KVICHAK RIVER SOCKEYE SALMON STOCK STATUS AND ACTION PLAN, 2000

by

Bristol Bay Staff

Regional Information Report[1] No. 2A00-37

Alaska Department of Fish and Game
Division of Commercial Fisheries
Regional Office
333 Raspberry Road
Anchorage, Alaska 99518-1599

December 2000

[1]Contribution 2A00-37 from the Anchorage regional office. The Regional Information Report Series was established in 1987 to provide an information access system for all unpublished divisional reports. These reports frequently serve diverse ad hoc informational purposes or archive basic uninterpreted data. To accommodate needs for up-to-date information, reports in this series may contain preliminary data.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203; or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 907-465-3646, or (FAX) 907-465-2440.

TABLE OF CONTENTS

Page

LIST OF TABLES v

LIST OF FIGURES vi

EXECUTIVE SUMMARY OF KVICHAK RIVER SOCKEYE SALMON STOCK STATUS 1

- *Synopsis* 1
- *Harvest* 1
- *Escapement* 2
- *Outlook* 2
- *Alaska Board of Fisheries Action* 2

SPAWNING ESCAPEMENT GOAL EVALUATION FOR KVICHAK RIVER SOCKEYE SALMON 9

- *Escapement Goal History* 9
- *Spawner-Return Data* 10
- *Yield Analysis* 11
- *Smolt Information* 12
- *Spawner Distribution* 13
- *Summary* 13
- *Escapement Goal Recommendations* 14

MANAGEMENT/ACTION PLAN OPTIONS FOR ADDRESSING STOCK OF CONCERN AS OUTLINED IN THE SUSTAINABLE FISHERIES POLICY 28

- *Kvichak River Sockeye Salmon Management Plan Review/Development* 28
    - Current Stock Status 28
    - C&T use finding and the amount necessary 28
    - Habitat Factors Adversely Affecting the Stock 28
    - Do New or Expanding Fisheries on this Stock Exist? 28
    - Existing Management Plans 28
    - Identify Research Needed on Stock 29

TABLE OF CONTENTS (Continued)

Page

Action Plan Development 30

Kvichak Sockeye Salmon Action Plan Goal 30
Action Plan Alternatives 30
Action 1 30
Action 2 32
Action 3 33
Action 4 35

Research Plan 38

Past Research and Publications 38
Unpublished Reports and Memorandums 40
Current Bristol Bay Research Projects 40
Current Bristol Bay Research Projects Funded and Operating Under Western Alaska Disaster Mitigation Funds 41
Proposed ADF&G Bristol Bay Research Projects 43
USGS – BRD, Alaska Biological Science Center, Bristol Bay Research Projects ... 45

LITERATURE CITED 47

LIST OF TABLES

Executive Summary of Kvichak River Sockeye Salmon Stock Status

Table — Page

1. Historical yield, escapement and total inshore return of Kvichak River sockeye salmon....... 3

2. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1968-1998 brood years, Kvichak River.............. 4

3. Comparison of recent pre-peak, peak and off-cycle yields to historical median yield for Kivchak River sockeye salmon 5

4. Escapement analysis for Kvichak River sockeye salmon, 1996-2000 6

Spawning Escapement Goal Evaluation for Kvichak River Sockeye Salmon

5. History of Kvichak River sockeye salmon escapement goals set under the cyclic goal policy, 1969-1985 and recent goals, 1986-2000, set under the 4-10 million policy range............... 15

LIST OF FIGURES

Executive Summary of Kvichak River Sockeye Salmon Stock Status

Figure Page

1. Map of Kvichak River drainage. 7

2. Kvichak River sockeye salmon yield by year 8

Spawning Escapement Goal Evaluation for Kvichak River Sockeye Salmon

3. Map of Bristol Bay showing major rivers and fishing districts 16

4. Number of spawners and total return of Kvichak River sockeye salmon by brood year, 1956-1995 17

5. Return per spawner of Kvichak River sockeye salmon by brood year, 1956-1995, and versus number of spawners 18

6. Return per spawner of Kvichak River sockeye salmon versus number of spawners for off-cycle, and pre-peak and peak cycle years (1956-1995 brood years) 19

7. Total return of Kvichak River sockeye salmon versus number of spawners, 1956-1995 brood years 20

8. Ricker spawner-recruitment relationship of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1960-1995 brood years) 21

9. Average surplus yield categorized by number of spawners of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1960-1995 brood years) 22

10. Number of sockeye salmon smolt migrating out of Kvichak River, 1971-2000 23

11. Number of spawners versus number of smolt, and number of smolt versus total adult return for Kvichak River sockeye salmon (1969-1995 brood years) 24

12. Number of spawners versus number of smolt of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1969-1995 brood years) 25

13. Average length and weight of age 1 and age 2 smolts versus number of spawners for Kvichak River sockeye salmon (1969-1995 brood years) 26

14. Spawner distribution of Kvichak River sockeye salmon at main beaches, island beaches, rivers, and creeks, 1961-2000 27

Executive Summary of Kvichak River Sockeye Salmon Stock Status

Synopsis

In response to the guidelines established in the "Sustainable Salmon Fisheries Policy" (ADF&G 2000), ADF&G has classified the Kvichak River sockeye salmon stock as a stock of concern. This classification is based on the definition of "yield concern" found in the policy. A "yield concern" is defined as, "a concern arising from a chronic inability, despite specific management measures, to maintain expected yields, or harvestable surpluses, above a stock's escapement needs." For this determination, the most recent 5-year period (one salmon life-cycle or generation) was compared to the Kvichak River data set from 1956 to 1995 (Table 1). Yields and escapements from 1999 and 2000 were compared to pre-peak and peak years only, and yields and escapements from 1996, 1997, and 1998 to off-cycle years only.

The high degree of variability over the 40-year span of the data set reflects the long-term cycles coinciding with changes in the Pacific Decadal Oscillation (Hare et al. 1999). It is plausible that the PDO is in the process of shifting to a less productive period for Bristol Bay salmon. The literature states that major PDO regimes have persisted for 20 to 30 years, the most recent shift occurring in 1976-77 and resulting in a period of high productivity for Bristol Bay salmon. A shift to a less favorable regime might suggest that Kvichak River yields of the last 5 years are expected and that higher yields might not be sustainable. If a PDO shift is occurring, this comparison of recent yields is better illustrated by using the entire Kvichak River data set (1956-95) than by using a recent 20-year data set (1976-95).

Based on smolt data, freshwater productivity in the Kvichak River system has been adequate in recent (last five years) times(Table 2). The 1996-2000 average smolt outmigration estimate is about 1.5 times greater than the 1983-1995 average and mean lengths and weights have been near average, suggesting that marine productivity has had the most impact on recent returning adult abundances.

Harvest

Table 3 and Figure 2 summarize the yield analysis for the Kvichak River. The actual yield was less than the median yield in all years (both peak and off-cycle) of the most recent 5-year period by 36% to 94%. The term "lower range of historic harvest" is not defined in the "Sustainable Salmon Fisheries Policy." Thus the degree of yield concern and the point at which a yield concern is classified are subject to interpretation. Figure 2 is provided to illustrate graphically the yield data for the recent 5 years in the context of historical values.

Escapement

Table 4 summarizes the escapement analysis for the Kvichak River. During the most recent 5 years, escapements did not meet the goal in 1996, 1997, and 2000. The off-cycle escapement goal was changed from 4,000,000 to 2,000,000 (variable) in 1997 (implemented in 1998). Escapements in 1996 and 1997 would not have met the current off-cycle goal of 2,000,000 although the shortfall is not alarming. ADF&G is concerned with the 70% shortfall in escapement during a Kvichak peak year (2000). There have been 2 pre-peak (1959 and 1964) and no peak year escapements which were less than the 2000 escapement. The Department feels that with the decrease in marine productivity indicated by recent smolt/return ratios and a possible PDO shift, the current trends in Kvichak River returns could continue.

Outlook

The 2001 sockeye salmon run for the Kvichak River is anticipated to be below average based on parent year and sibling returns. Typically, the majority of Kvichak River sockeye salmon are 4 and 5 year-old 2-ocean fish. The parent years for this 2-ocean component were below average. In a normal post-peak Kvichak River return, substantial numbers of 5 and 6 year-old, 3-ocean fish could be expected, however, the 2000 return does not indicate that this will be the case. Recent off-cycle returns when coupled with parent year and sibling returns, would indicate a below average return for 2001 and thus a harvest in the below average category for off-cycle harvests.

Alaska Board of Fisheries Action

In response to the guidelines established in the Sustainable Salmon Fisheries Policy, the Alaska Board of Fisheries, during the 9/28-29/00 workshop, classified the Kvichak River sockeye salmon stock as a yield concern.

Table 1. Historical yield, escapement and total inshore return of Kvichak River sockeye salmon.

	Actual Yield		Actual Escapement		Total Inshore Return	
Year	Pre-Peak & Peak	Off-cycle	Pre-Peak & Peak	Off-Cycle	Pre-Peak & Peak	Off-Cycle
1956		4,168,343		9,443,318		13,611,661
1957		3,540,189		2,842,810		6,382,999
1958		549,396		534,785		1,084,181
1959	281,930		680,000		961,930	
1960	7,976,500		14,630,000		22,606,500	
1961		6,863,814		3,705,849		10,569,663
1962		1,833,401		2,580,884		4,414,285
1963		223,459		338,760		562,219
1964	763,486		957,120		1,720,606	
1965	17,785,664		24,325,926		42,111,590	
1966		4,168,575		3,775,184		7,943,759
1967		1,800,652		3,216,208		5,016,860
1968		387,565		2,557,440		2,945,005
1969	3,760,565		8,394,204		12,154,769	
1970	16,581,224		13,935,306		30,516,530	
1971		3,764,861		2,387,392		6,152,253
1972		342,150		1,009,962		1,352,112
1973		21,791		226,554		248,345
1974	148,595		4,433,844		4,582,439	
1975	1,605,407		13,140,450		14,745,857	
1976		1,458,180		1,965,282		3,423,462
1977		739,464		1,341,144		2,080,608
1978		3,815,636		4,149,288		7,964,924
1979	13,418,829		11,218,434		24,637,263	
1980	12,743,074		22,505,268		35,248,342	
1981		5,234,733		1,754,358		6,989,091
1982		1,858,475		1,134,840		2,993,315
1983		16,534,901		3,569,982		20,104,883
1984	12,523,803		10,490,670		23,014,473	
1985	6,183,103		7,211,046		13,394,149	
1986		787,303		1,179,322		1,966,625
1987		3,526,824		6,065,880		9,592,704
1988		2,654,364		4,065,216		6,719,580
1989	11,456,509		8,317,500		19,774,009	
1990	10,551,217		6,970,020		17,521,237	
1991		3,808,873		4,222,788		8,031,661
1992		5,718,947		4,725,864		10,444,811
1993		5,287,523		4,025,166		9,312,689
1994	13,893,613		8,337,840		22,231,453	
1995	17,391,906		10,138,720		27,530,626	
MED	11,003,863	3,090,594	9,266,462	2,711,847	21,002,731	6,267,626
MAX	17,785,664	16,534,901	24,325,926	9,443,318	42,111,590	20,104,883
MIN	148,595	21,791	680,000	226,554	961,930	248,345
1996		1,983,269		1,450,578		3,433,847
1997		179,480		1,503,732		1,683,212
1998		1,069,294		2,296,074		3,365,368
1999	6,392,296		6,196,914		12,589,210	
2000	1,026,986 [a]		1,827,780		2,854,766	

[a] 2000 yield is a preliminary estimate.

Table 2. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1968-1998 brood years, Kvichak River.

		Age 1.			Age 2.		
Brood Year	Total Spawning Escapement [a]	Number of Smolt	Adult Returns [b]	Adult Returns per Smolt	Number of Smolt	Adult Returns [b]	Adult Returns per Smolt
1968	2,557,440	-			5,959,383	209,138	0.04
1969	8,394,204	85,723,430	449,791	0.01	54,159,340	4,824,026	0.09
1970	13,935,306	464,219	56,778	0.12	191,842,930	15,351,498	0.08
1971	2,387,392	5,123,400	337,314	0.07	21,423,246	2,489,981	0.12
1972	1,009,962	2,740,610	436,837	0.16	-	1,504,435	[c]
1973	226,554	-	1,606,766	[c]	3,031,287	818,529	0.27
1974	4,433,844	108,326,892	8,353,542	0.08	114,269,848	17,796,617	0.16
1975	13,140,450	78,308,251	6,920,452	0.09	213,364,470	31,164,576	0.15
1976	1,965,282	32,226,544	6,132,390	0.19	26,423,348	4,431,284	0.17
1977	1,341,144	28,758,191	2,912,441	0.10	10,410,467	309,369	0.03
1978	4,149,288	182,442,540	2,991,655	0.02	32,294,536	2,151,024	0.07
1979	11,218,434	219,928,232	20,621,724	0.09	89,300,703	21,516,038	0.24
1980	22,505,268	150,421,026	4,534,253	0.03	76,244,773	8,508,770	0.11
1981	1,754,358	6,549,125	1,019,361	0.16	37,595,987	1,098,376	0.03
1982	1,134,840	51,893,988	995,144	0.02	1,937,408	663,241	0.34
1983	3,569,982	23,590,443	11,612,066	0.49	53,260,693	1,773,442	0.03
1984	10,490,670	83,470,460	4,455,429	0.05	331,384,545	19,478,848	0.06
1985	7,211,046	11,178,398	2,313,349	0.21	87,004,194	15,069,258	0.17
1986	1,179,322	13,126,363	1,791,108	0.14	6,830,717	2,722,727	0.40
1987	6,065,880	146,603,154	6,706,260	0.05	41,434,534	5,229,846	0.13
1988	4,065,216	46,569,569	4,982,204	0.11	34,266,421	4,961,033	0.14
1989	8,317,500	87,187,761	3,829,838	0.04	61,317,308	22,259,220	0.36
1990	6,970,020	18,172,700	2,740,515	0.15	204,626,879	22,351,535	0.11
1991	4,222,788	21,781,009	3,927,255	0.18	30,207,268	870,852	0.03
1992	4,725,864	53,638,204	655,398	0.01	11,034,144	743,926	0.07
1993	4,025,166	209,857,983	1,750,572	0.01	96,434,554	1,180,762	0.01
1994	8,337,840	276,731,978	2,987,502	0.01	94,049,964	3,972,452 [d]	0.04 [d]
1995	10,038,720	269,347,699	9,473,554 [d]		103,481,449	513,662 [d]	
1996	1,450,578	191,989,401	362,150 [d]		12,200,727	0 [d]	
1997	1,503,732	131,342,488	0 [d]		23,859,650	[d]	
1998	2,296,074	106,178,999	[d]				
1984-1993 Max	10,490,670	209,857,983	6,706,260	0.21	331,384,545	22,351,535	0.40
1984-1993 Avg	5,727,347	69,158,560	3,315,193	0.09	90,454,056	9,486,801	0.15
1984-1993 Min	1,179,322	11,178,398	655,398	0.01	6,830,717	743,926	0.01

[a] Kvichak River tower count only. Does not include aerial survey index counts from Branch River.

[b] Includes estimates of adult returns through 2000. Current year adult return data from Bristol Bay Sockeye Total Run - 2000 (Gray, 9/27/00).

[c] Insufficient smolt samples collected to perform this calculation.

[d] Future adult returns will increase these values.

Table 3. Comparison of recent pre-peak, peak and off-cycle yields to historical median yield for Kvichak River sockeye salmon.

Year	Actual Yield	Median Yield: Pre-Peak & Peak 1959-95, n = 16	Median Yield: Off-cycle 1956-93, n = 24	Difference	% deviation from Med. [a]	Yield < Lower Range [b]	Frequency of Occurrence[c]
1996	1,983,269		3,090,594	-1,107,325	-36	No	11 (n=24)
1997	179,480		3,090,594	-2,911,114	-94	No	1 (n=24)
1998	1,069,294		3,090,594	-2,021,300	-65	No	7 (n=24)
1999	6,392,296	11,003,863		-4,611,567	-42	No	6 (n=16)
2000	1,200,000 [d]	11,003,863		-9,803,863	-89	No	3 (n=16)

[a] Percent deviation = (Actual - Median) / Median

[b] Lower range of Pre-Peak and Peak years was 148,595 and Off-cycle years was 21,791.

[c] The number of yield observations (1956-1995) which are less than the yield of the current year

[d] 2000 Yield is a preliminary estimate.

Table 4. Escapement analysis for Kvichak River sockeye salmon, 1996-2000.

Year	Actual Escapement	Escapement Goal	Difference	% deviation from Goal [a]	Escapement > Goal	Frequency of Occurrence[b]
1996	1,450,578	4,000,000	-2,549,422	-64	No	7 (n=24)
1997	1,503,732	4,000,000	-2,496,268	-62	No	7 (n=24)
1998	2,296,074	2,000,000	296,074	15	Yes	9 (n=24)
1999	6,196,914	6,000,000	196,914	3	Yes	3 (n=16)
2000	1,827,780	6,000,000	-4,172,220	-70	No	2 (n=16)

[a] Percent deviation = (Actual - Goal) / Goal

[b] The number of escapement observations (1956-1995) which are less than the escapement of the current year

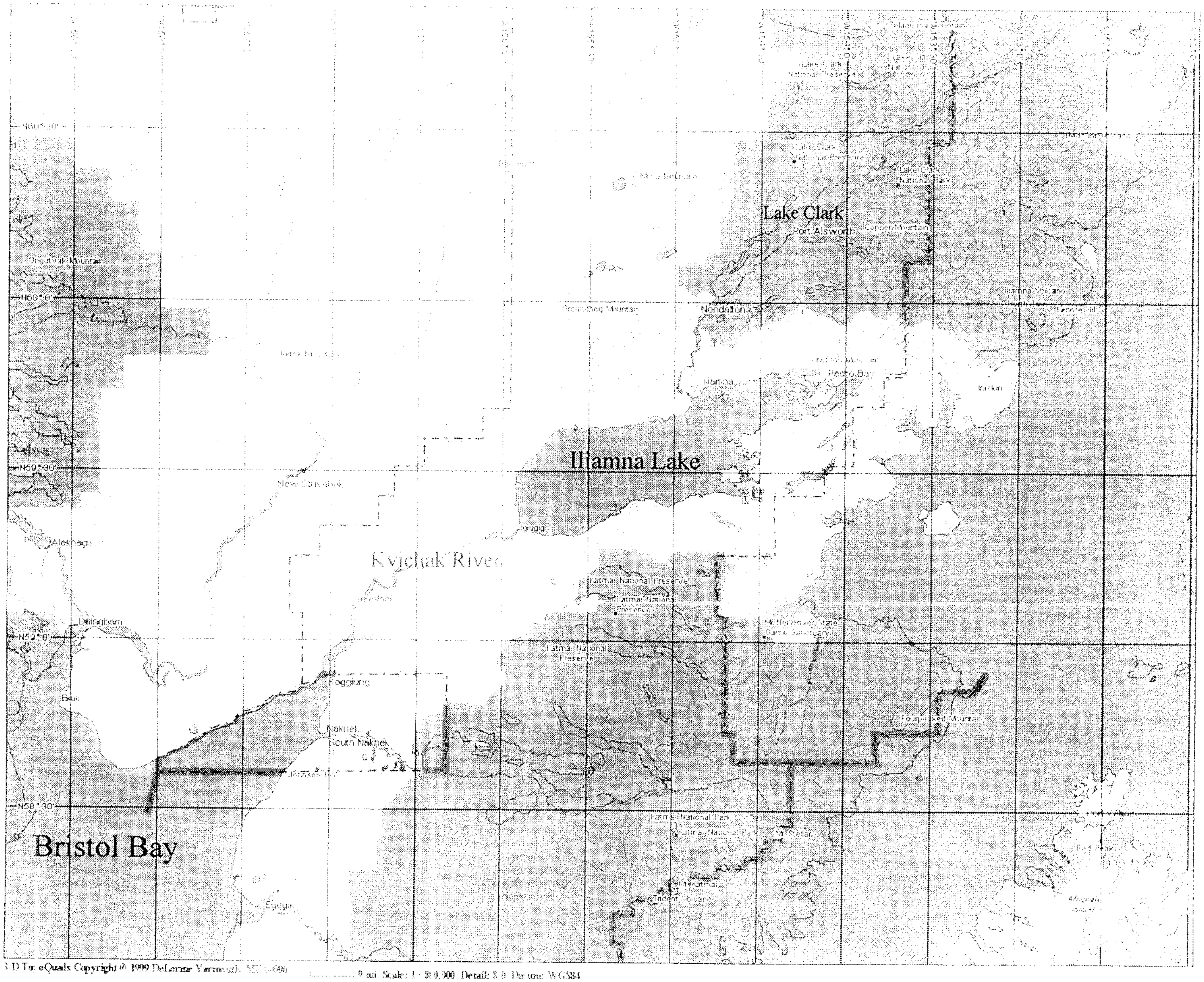
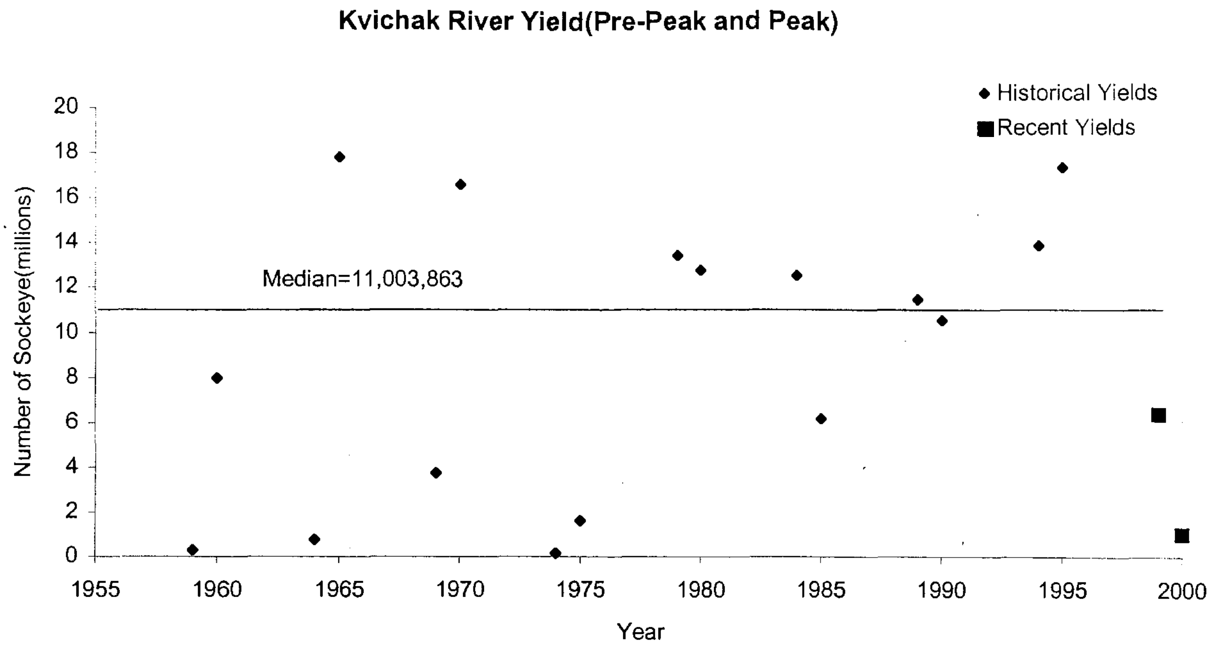


Figure 1. Map of Kvichak River drainage



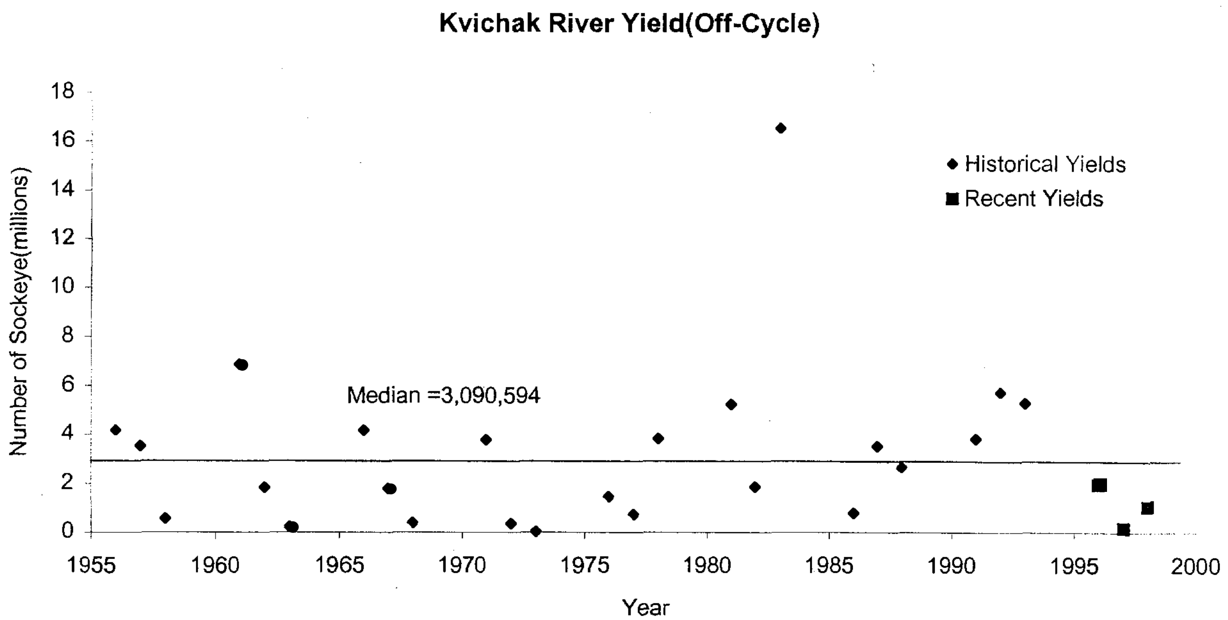


Figure 2. Kvichak River sockeye salmon yield by year.

SPAWNING ESCAPEMENT GOAL EVALUATION FOR KVICHAK RIVER SOCKEYE SALMON

Escapement Goal History

The management strategy for the Kvichak River from 1962 through 1984 was based on the occurrence of cyclic dominance in which some depensatory mechanism, independent of the fishery, was thought to suppress production during each of three years following a subdominant and dominant year. Since the five-year cycle was thought to be a naturally occurring phenomenon, management sought to obtain cyclic spawning escapements. Fishing in the Naknek-Kvichak District was regulated to obtain intermediate spawning escapements (4 million to 6 million) for the pre-peak (sub-dominant) run, large spawning escapements (10 million to 15 million) for the peak (dominant) run, and small spawning escapements (1 million to 2 million) for the three off-cycle years (Table 1).

Changes in the Kvichak River run since 1978, particularly the occurrence of large runs during off-cycle years like 1983, prompted reexamination of management based on the cyclic dominance theory. Results from analyses conducted by Rogers and Poe (1984) and Eggers and Rogers (1987) suggested that the Kvichak River run cycles were largely caused by a combination of: 1) weather; 2) small spawning escapements; and 3) brood year interaction between peak-cycle years which had very large escapements and the following brood years that experienced reduced production. Eggers and Rogers (1987) suggested that the commercial fishery was the depensatory factor responsible for the recent pronounced cycle, because off-cycle runs were exploited at much greater rates than either pre-peak or peak runs.

In 1985, ADF&G adopted an escapement goal policy to moderate the Kvichak run cycle (Fried 1984). Spawning escapement goals were increased for off-cycle years and decreased for the peak year to moderate future fluctuations in production. Since that time, four BEG evaluation meetings have been held, including the 2000 meeting documented within this report. Results from the 1987, 1991, 1994, and 1997 meetings have been presented to the Board of Fisheries (Cross 1991, Cross 1994, Cross et al. 1997).

The Kvichak escapement goal policy adopted in 1987 and continued through 2000 has allowed annual spawning escapement goals to fluctuate within a range of 2 to 10 million sockeye salmon. The lower limit of 2 million spawners was established because escapements below this level had often produced poorly. The upper limit of 10 million spawners was established because escapements greatly above this level appeared to reduce production the following brood year. A range of goals, rather than a single goal, was established to allow for 1) fluctuations in run sizes; 2) variations in spawner distribution; 3) potential effects of brood year interactions between progeny of successive spawning escapements; and 4) increased information on returns from spawning escapements between 2-10 million. We now have five returns from off-cycle escapements between 4-6 million. Two of those brood years (1987 and 1988) produced good runs ranging from 10-12 million, while the remaining three brood years produced poor runs ranging from 2-5 million.

In 1997, BEG workshop participants agreed that the escapement goal policy for Kvichak River should be modified to allow for a more robust variable escapement goal range based on actual run size and a conservative exploitation rate (Table 2). The BEG range for Kvichak River during off-cycle years was changed from 4-6 million to a broader range of 2-10 million. Additionally, an exploitation rate of 50% was set on runs of 4-20 million to provide guidance in setting goals within the range. The management objective for a given off-cycle year would then be defined as 50% of the total inshore Kvichak River run, and would never be less than 2 million or greater than 10 million. The management objective for a given pre-peak or peak cycle year would then be defined as 50% of the total inshore Kvichak River run, and would never be less than 6 million or greater than 10 million. This would provide opportunity to obtain large escapements during the exceptional off-cycle year in which a run was large, but would also allow more harvest during the more usual off-cycle year in which a run was small. For example, under the new policy, an off-cycle total return of 8 million would allow 4 million for escapement and 4 million for catch while a peak or pre-peak return of 14 million would allow for an escapement of 7 million and a harvest of 7 million.

Spawner-Return Data

The number of Kvichak River spawners has ranged from 0.2 million in 1973 to 24.3 million in 1965 and returns have ranged from 0.3 million for brood year 1958 to 55.0 million for brood year 1960 (Figure 2; Appendix Table B.1). Kvichak River spawner-return data from 1956-1995 show very distinct five-year cycles: two years of high production (pre-peak and peak cycle years) followed by three years of low production (off-cycle years). Through 1995, the average number of spawners for pre-peak and peak cycle years has been 10.3 million, and the average number of returning adults has been 22.3 million, however, there has been a downward trend in production since 1960. The average number of spawners for off-cycle years has been 3.0 million with the average number of returning adults at 5.9 million. There has been little overlap in spawning population sizes between off-cycle (10-90th percentile range: 0.7-4.6 million) and peak (10-90th percentile range: 2.7-18.7 million) years. This makes it difficult to determine whether large escapements would produce well during off-cycle years, or whether small escapements obtained during peak years would produce well or result in increased production during subsequent off-cycle years.

Return-per-spawner values for the Kvichak River have ranged from 0.2 for brood year 1968 (2.5 million spawners) to 10.8 for brood year 1973 (0.2 million spawners) and averaged 2.4 for all available brood years (Figure 3; Appendix Table B.1). Return-per-spawner values have increased slightly since brood year 1972 (Figure 3). However, the past five brood year return-per-spawner values have been below the 1956-1972 and 1973-1995 averages, but have been increasing slightly each year since 1992. The average return-per-spawner was 1.9 during 1956-1972 and increased to 2.8 during 1973-1995. Additionally, return-per-spawner values fell below replacement for 6 of 17 brood years (38%) during 1956-1972 while return-per-spawner values only fell below replacement for 4 of 23 brood years (17%) during 1973-1995. When viewing the entire series of available brood years, no distinct trends between return-per-spawner values and numbers of spawners were obvious. Density-dependent mortality was not evident since return-per-spawner values did not decrease as escapements increased (Figure 3). No strong trends were apparent when brood year data were divided into off-cycle and peak years. Return-per-spawner values were similar between off-cycle and peak cycle years during 1956-1995. Average return per spawner for off-cycle brood years was 2.3, while the average for pre-peak and peak cycle brood years was 2.5 (Figure 4). There was a slight trend of decreasing return-per-spawner values with increasing escapements within off-cycle brood years as well as within peak cycle brood years. Unexpectedly however, the average return-per-spawner value was slightly lower for off-cycle brood years than it was for pre-peak and peak brood years, even though the average number of spawners during off-cycle years has been considerably less than that for pre-peak and peak years. Again, return-per-spawner information did not indicate that freshwater density-dependent mortality was an important factor in determining production.

A Ricker stock-recruitment model could not be fitted to spawner-return data for the Kvichak River when all brood years were examined as a set (Figure 5). A significant fit (P=0.11) did occur however, if years 1969-1995 were included in the model; the estimated number of spawners required to produce MSY was 8.2 million. When all the data were separated into off-cycle years, a significant (P=0.11) Ricker model indicated that MSY was achieved with 1.9 million spawners (bootstrapped 80% confidence interval of 1.3-3.7 million, n=1000; Figure 6). A Ricker model also produced a significant fit (P=0.09) to pre-peak and peak spawner-return data (1959 excluded), and indicated that MSY was achieved at 9.5 million spawners (bootstrapped 80% confidence interval of 6.0-19.0 million, n=1000; Figure 6). We must caution the reader that fitting Ricker models to off-cycle and peak cycle data separately could produce misleading results, since this assumes that available spawner-return data can be used to describe the stock-recruitment relationship for both cycle year categories. As mentioned previously however, while the data set as a whole has good contrast in numbers of spawners (range: 0.2 million to 24.3 million), off-cycle years within the available data set have had much smaller escapements than pre-peak and peak years. The lack of contrast in number of spawners for both subsets of the data does not allow us to determine whether off-cycle and peak years actually have different production regimes or whether observed differences are simply due to number of spawners.

Yield Analysis

A tabular approach to examine spawner-return data indicated that spawning populations between 1-2 million (n=6) and 3-4 million (n=4) produced the greatest ASY of 2.6 million for the off-cycle brood years (Figure 7). Other spawning levels produced considerably lower ASYs (less than 1.0 million). Spawning populations between 12-15 million (n=3) produced the greatest ASY (22.5 million) for the data set containing only pre-peak and peak years (Figure 7). The next highest category contained spawning escapements from 9-12 million, which produced an ASY of 15.0 million (n=3). No other categories produced ASYs greater than 10 million. The current BEG for pre-peak and peak cycle years is 6-10 million. The minimum goal of 6 million was established because most pre-peak and peak cycle escapements had been greater than or equal to 6 million spawners and had produced good returns. The 10 million maximum was based on evidence that escapements greater than this depressed production from subsequent escapements (Eggers and Rogers 1987).

Smolt Information

Prior to 2000, there were five consecutive years of large age-1 smolt outmigrations, while previous large smolt migrations were predominantly age-2 smolt (Figure 8). Freshwater age of Kvichak River sockeye salmon appears to be determined by environmental conditions such as warm weather during April through October (Rogers and Poe 1984). However, Lew and Schindler (University of Washington, FRI, personal communication) found that larger escapements in Iliamna Lake tend to produce a larger proportion of age-2 smolts, which in turn, have a higher marine survival. Large escapements increase food competition in Iliamna Lake, slowing the growth of juvenile sockeye salmon. Freshwater age is partially determined by growth, and slower growing fish tend to stay in freshwater longer before leaving the lake systems as smolt. Brood years with unusually warm weather (1992-1995) have produced greater proportions of age-1. smolt.

There was a significant ($P<0.001$) positive relationship between numbers of smolt and numbers of spawners for all brood years (Appendix Table C.1 and Figure 9). There was also a significant ($P=0.01$) positive relationship between numbers of adult returns and numbers of smolt. The relationship between numbers of smolt and numbers of spawners for off-cycle brood years was positive for both age-1 ($P=0.02$), and age-2 ($P=0.06$; Figure 10) smolt. With the exception of brood years 1978, 1987, and 1993, most off-cycle brood years have produced 80 million or fewer smolt. High smolt production from off-cycle brood years has been predominantly age-1. smolt from spawning escapements of 4 million or more sockeye salmon. Therefore, smolt information suggested that smolt production may be increased by allowing greater numbers of sockeye salmon to spawn during off-cycle years. We found no significant relationship between numbers of smolt and numbers of spawners for pre-peak and peak years (Figure 10).

Significant inverse relationships were found among size of age-1. and age-2. smolt and numbers of spawners (Figure 11). Decreasing average size of smolt with increasing numbers of spawners was probably due to juveniles competing for food because more smolt were produced from brood years with greater numbers of spawners. Due to differences in numbers of spawners and numbers of smolt produced by different brood years within the cycle, average size of smolt was larger for off-cycle than for pre-peak and peak brood years. Average length of age-1. smolt was 87 mm for off-cycle brood years and 85 mm for pre-peak and peak brood years. Average length of age-2. smolt was 108 mm for off-cycle brood years and 101 mm for pre-peak and peak brood years. Similarly, average weight of off-cycle age-1. smolt was 6.0 g and for pre-peak and peak cycle age-1. smolt it was 5.5 g. Average weight for off-cycle age-2. smolt was 10.7 g and of pre-peak and peak cycle age-2. smolt it was 9.0 g. Although average size of smolt produced by pre-peak and peak brood years was less than that of smolt produced by off-cycle brood years, marine survival was not statistically different between off-cycle and pre-peak and peak brood years.

The average smolt per spawner for off-cycle brood years was 30 and for pre-peak and peak brood years, it was 27 (Appendix C.1). The rate of smolt production was not different between off-cycle years compared to pre-peak and peak years, indicating that inherent production did not differ, only the numbers of spawners.

Spawner Distribution

Distribution of spawners among spawning habitat types has varied considerably throughout the years, but two trends were evident (Figure 12). Cycles seemed to have moderated after 1987 for runs to the various spawning habitats except for island beaches where runs still show a strong five-year cycle. Spawners occurred in appreciable numbers on the island beaches only during the dominant peak years. Also, there appeared to be a decreasing number of island beach spawners from 1965-2000. Some of this decrease may have been due to a change in the aerial survey program, beginning in 1988, rather than to a real decrease in spawner abundance. Prior to 1988, aerial surveys were conducted over a longer time period each year, which increased the probability of surveying during peak spawning periods. Beginning in 1988, the number of replicate surveys has been reduced, so timing of individual surveys has become more important. The most accurate aerial counts of beach spawners are made during peak spawning activity, since spawners are difficult to see in these areas and carcasses most likely sink into deep water where they are not visible. Some decline in beach spawners was noticeable prior to 1988. This may indicate that the decline is real, but that changes in the aerial survey program may have accentuated its appearance. Large total numbers of spawners may be needed to get appreciable numbers spawning on island beaches, so island beach spawners cycle in abundance along with the total spawning population.

Summary

Extensive review of spawner-recruit, smolt, fry, and limnological information did not provide conclusive evidence supporting either of two hypothesis concerning the production cycles in Kvichak River: 1) the cycle is natural and caused by an unknown depensatory agent (e.g. predators); or 2) the cycle is simply due to low number of spawners during off-cycle years. A review of spawner-recruit data for all brood years suggested that the cycle was only due to a low number of spawners. Smolt-per-spawner values indicated that the rate of production from off-cycle brood years was similar to that for pre-peak and peak cycle years. In addition, smolt information from off-cycle years indicated that for some brood years with 4 million or more spawners, greater numbers of age-1. smolt were produced. These information indicated that the difference in production from off-cycle years compared to pre-peak and peak cycle years was only due to a lack of spawners.

An analysis of spawner-return data with off-cycle brood years examined separately suggested that yield decreased during off-cycle years for escapements greater than 4 million. The five observations from off-cycle escapements greater than 4 million produced lower than expected.

Spawner distribution information indicated that cycles appeared to be very pronounced for island beaches. This information indicated that cycles may be caused from some inherent depensatory factor.

Available information was inconclusive about the cause of production cycles in Kvichak River, therefore a great deal of uncertainty exists as to what levels of escapement will optimize Kvichak River's production every year. Unless additional information is collected that explains the cause of the production cycles, we will not be able to adequately address how to optimize the management of Kvichak River sockeye salmon.

Escapement Goal Recommendations

After reviewing the goals for the Kvichak River, there is some evidence that lowering the goal of 2 million spawners may increase yield in off-cycle years. For example, the suggested maximum sustainable yield from a Ricker spawner-recruit model is near the lower goal and an ASY analysis indicates that additional yield could be gained by lowering the goal below 2 million spawners. However, it was the consensus of the participants at the workshop that lowering the goal below 2 million spawners would increase the likelihood that some stocks would not receive an adequate number of spawners to maintain sustainability or genetic biodiversity within the drainage. BEG means the escapement that provides the greatest potential for maximum sustainable yield and ensuring the greatest potential means that diversity needs to be maintained. The Kvichak River run is composed of a complexity of spawning stocks and by maintaining the health of all stocks, periods of high productivity are more likely to result in strong returns.

Additionally, the lower goal of 2.0 million spawners for off-cycle years remained unchanged because if in fact, the cause for cyclic runs in the Kvichak is a lack of spawners meaning that there's no difference in productivity between what we currently consider cycle and off-cycle runs, then by lowering the goal of 2.0 million, we would be allowing escapements that are further from sustainable yield spawning levels. Therefore, the current BEG range for Kvichak River during pre-peak and peak cycle years was retained at 6-10 million and for off-cycle years at 2-6 million (Table 2).

Table 5. History of Kvichak River sockeye salmon escapement goals set under the cyclic goal policy, 1969-1985 and recent goals, 1986-2000, set under the 4-10 million policy range.

Year	Policy	Goal	Actual	Deviation[a]
1969	Cyclic	6,000,000	8,394,204	40
1970	"	19,000,000	13,935,306	-27
1971	"	2,500,000	2,387,392	-4
1972	"	2,000,000	1,009,962	-49
1973	"	2,000,000	226,554	-89
1974	"	6,000,000	4,433,844	-26
1975	"	14,000,000	13,140,450	-6
1976	"	2,000,000	1,965,282	-2
1977	"	2,000,000	1,341,144	-33
1978	"	2,000,000	4,149,288	107
1979	"	6,000,000	11,218,434	87
1980	"	14,000,000	22,505,268	61
1981	"	2,000,000	1,754,358	-12
1982	"	2,000,000	1,134,840	-45
1983	"	2,000,000	3,569,982	78
1984	"	10,000,000	10,490,670	5
1985	"	10,000,000	7,211,046	-28
1986	2-10 Range	5,000,000	1,179,322	-76
1987	"	5,000,000	6,065,880	21
1988	"	5,000,000	4,065,216	-19
1989	"	8,000,000	8,317,500	4
1990	"	6,000,000	6,970,020	16
1991	"	4,000,000	4,222,788	5
1992	"	6,000,000	4,725,864	-21
1993	"	5,000,000	4,025,166	-19
1994	"	8,000,000	8,337,840	4
1995	"	10,000,000	10,038,720	<1
1996	"	4,000,000	1,450,578	-64
1997	"	4,000,000	1,503,732	-62
1998	"	2,000,000	2,296,074	15
1999	"	6,000,000	6,196,914	3
2000	"	6,000,000	1,827,780	-70
1969-2000 Average		5,900,000	5,600,000	-9
1969-1985 Average		6,100,000	6,400,000	3
1986-2000 Average		5,600,000	4,800,000	-23

[a] Percent deviation = (Actual-Goal)/Goal

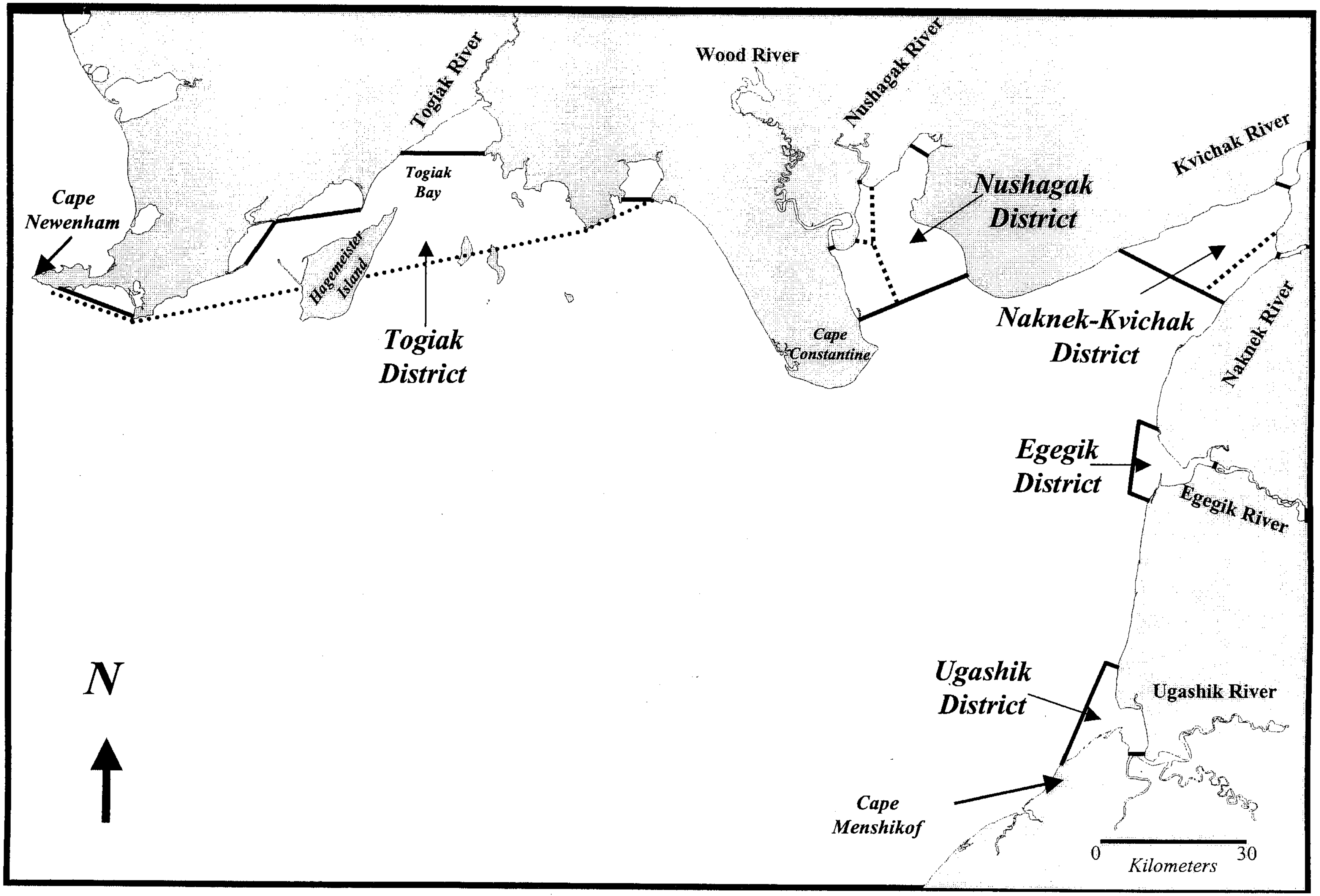


Figure 3. Map of Bristol Bay showing major rivers and fishing districts.

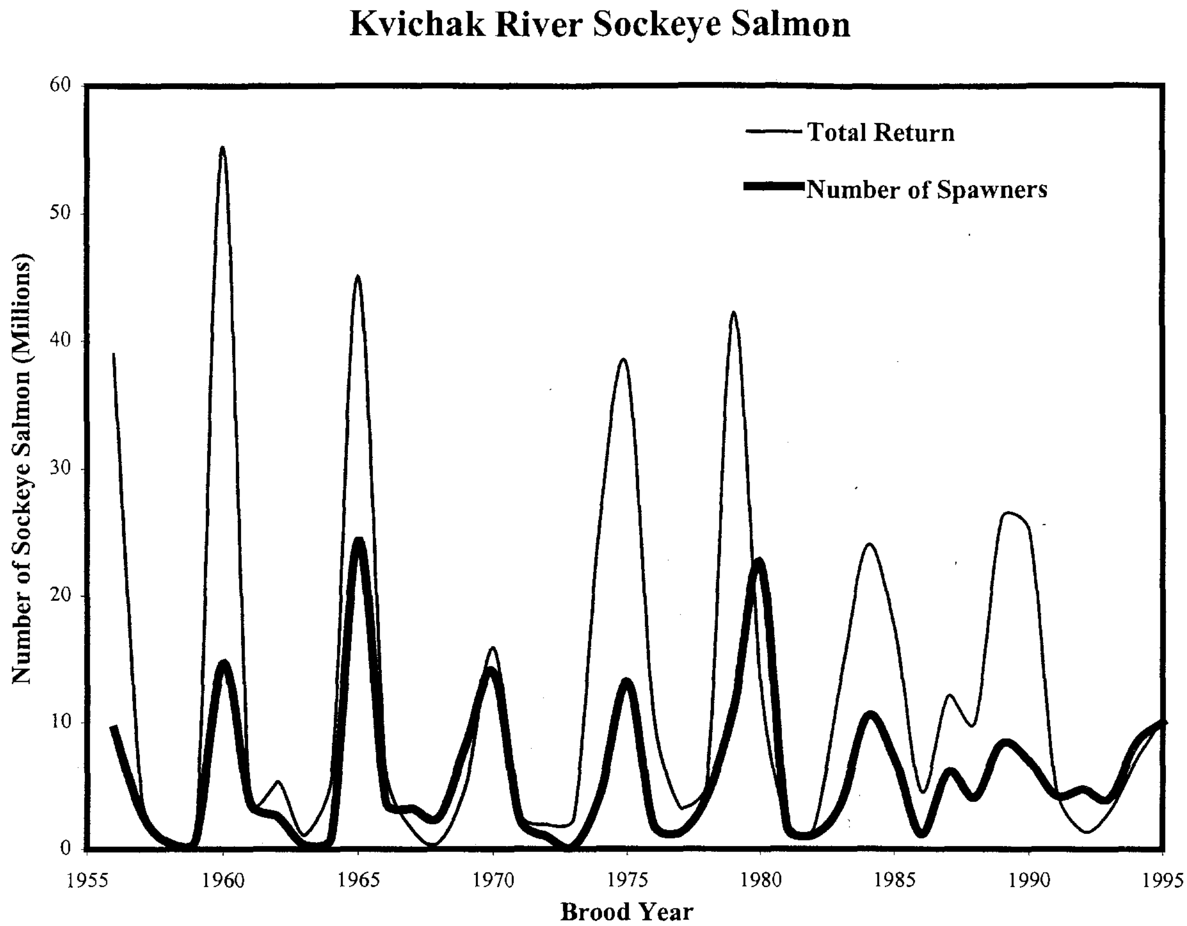


Figure 4. Number of spawners and total return of Kvichak River sockeye salmon by brood year, 1956 - 1995.

Kvichak River Sockeye Salmon

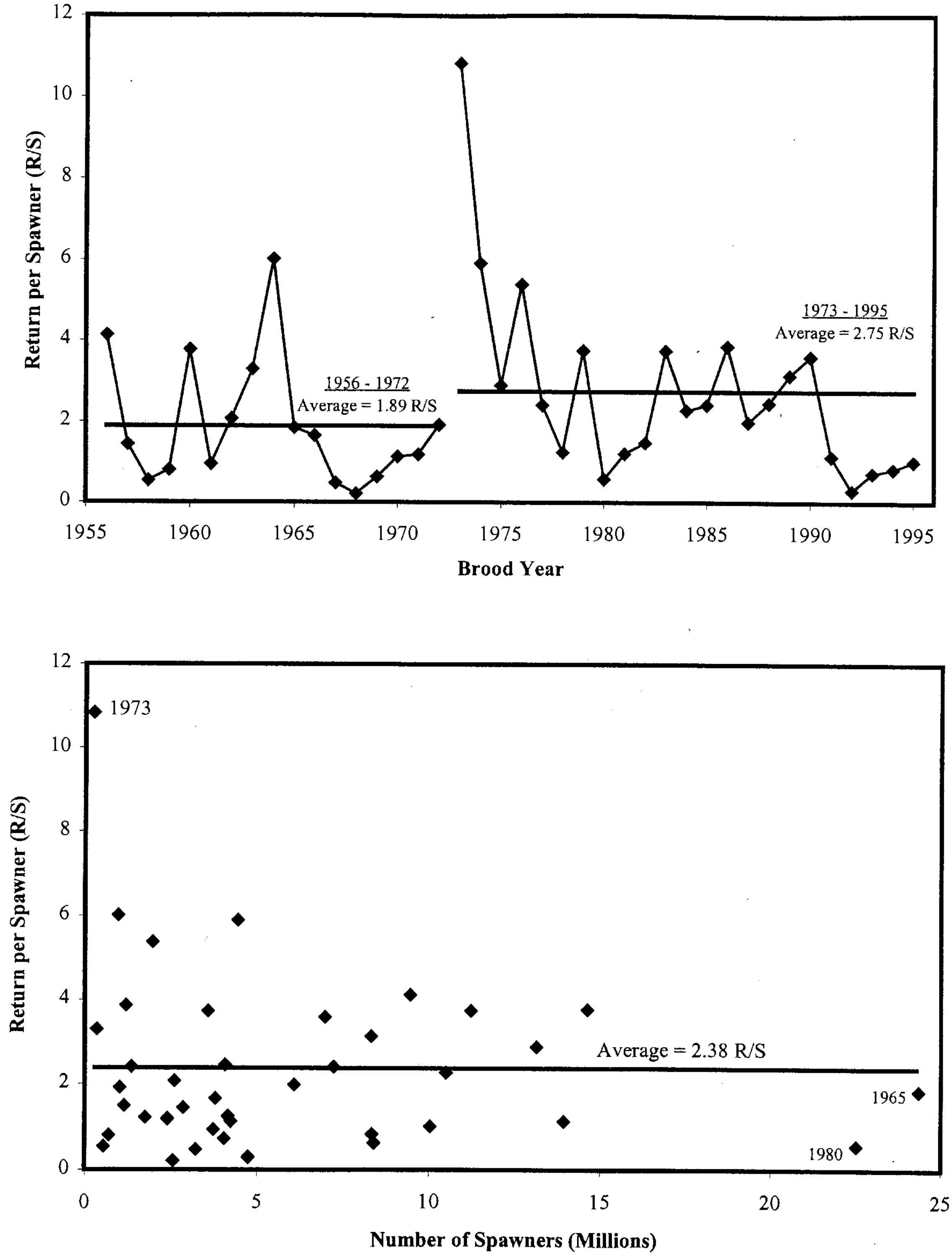


Figure 5. Return per spawner of Kvichak River sockeye salmon by brood year, 1956-1995, and versus number of spawners.

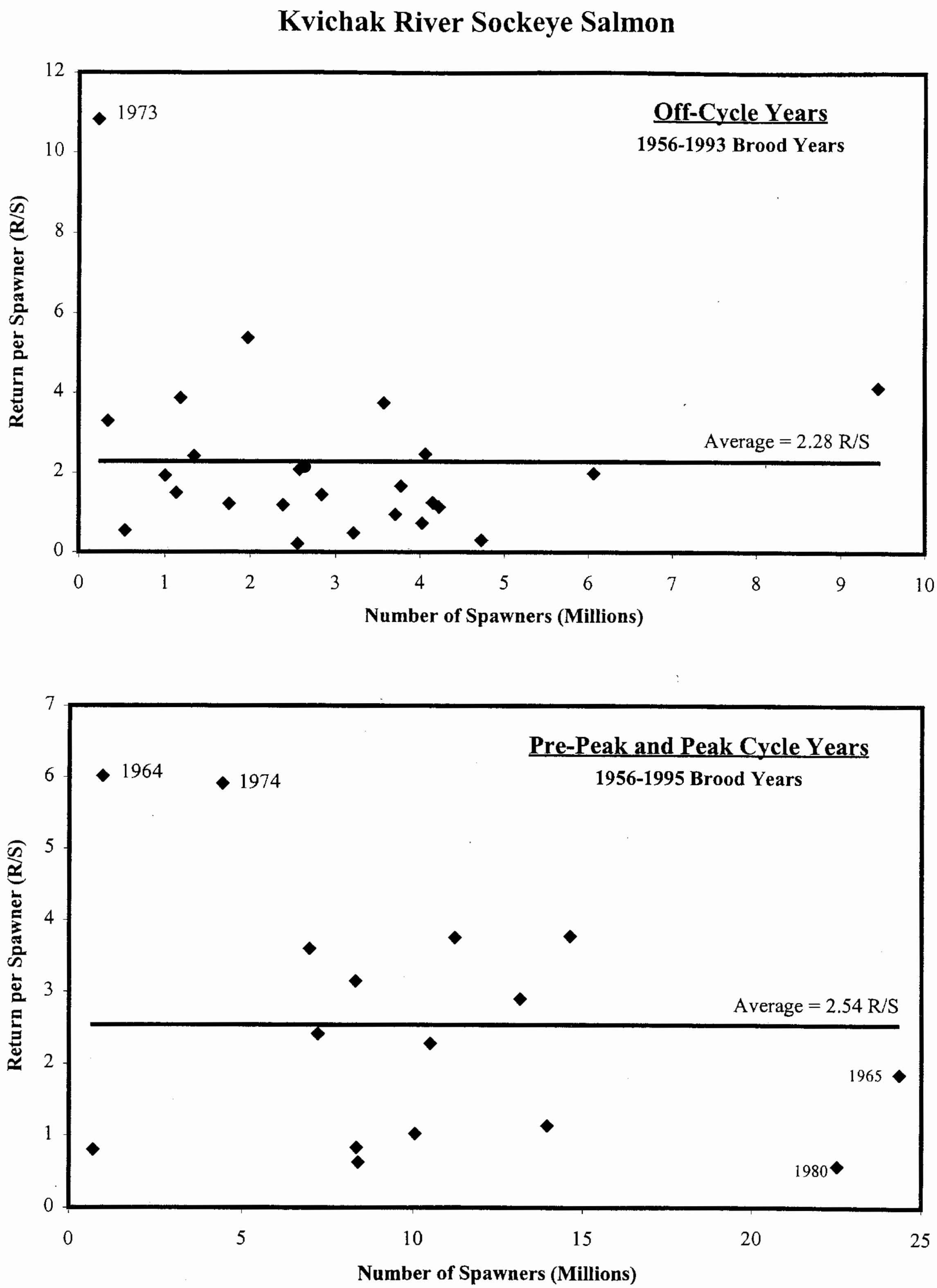


Figure 6. Return per spawner of Kvichak River sockeye salmon versus number of spawners for off-cycle, and pre-peak and peak cycle years (1956-1995 brood years).

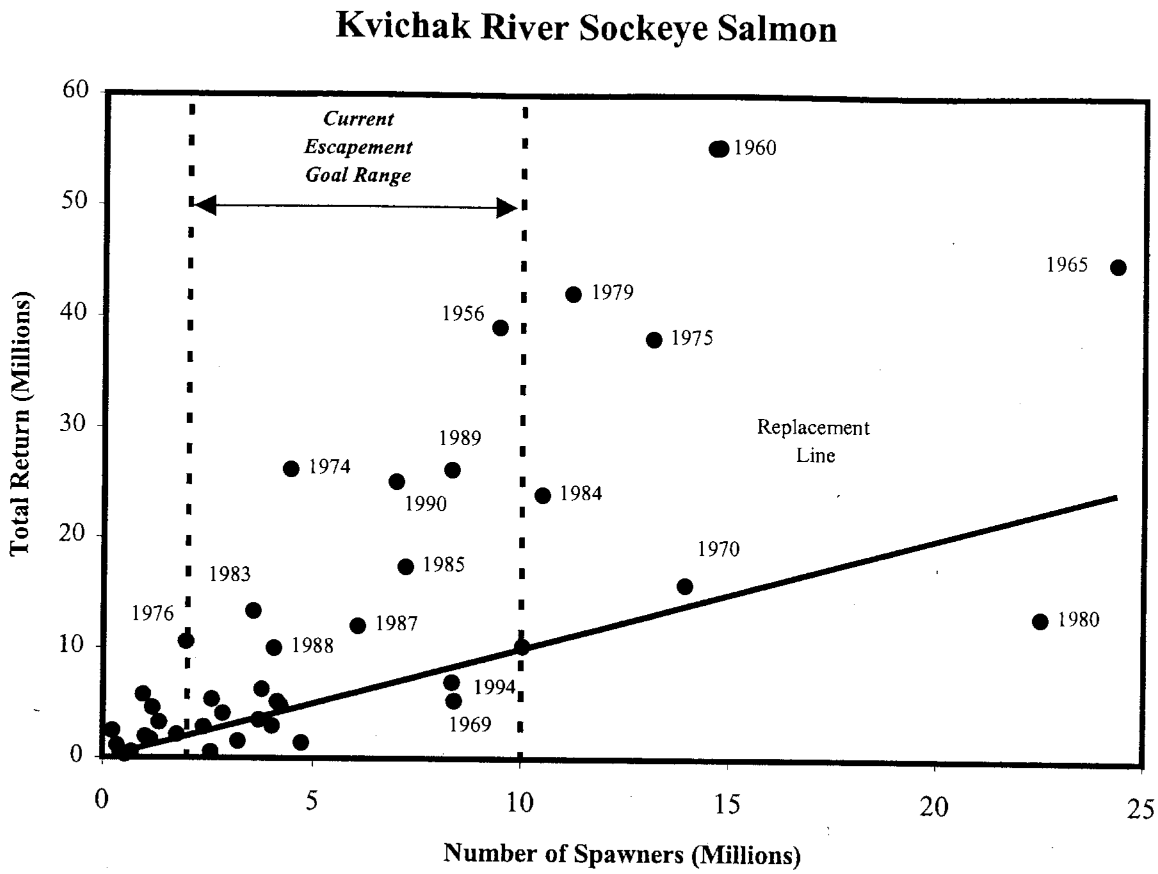
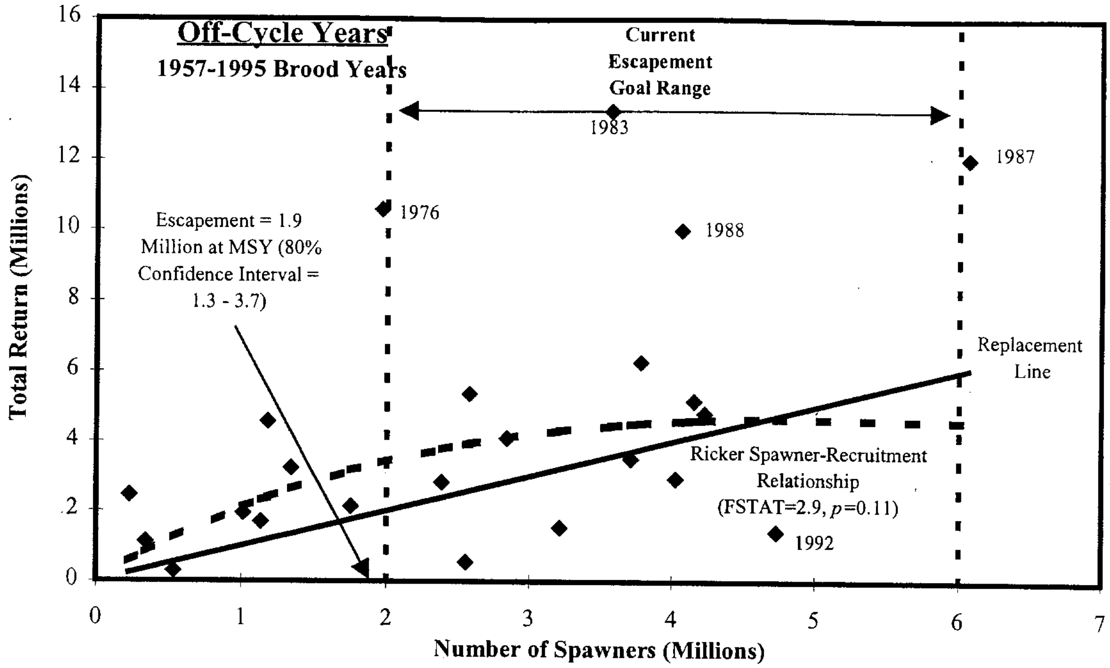


Figure 7. Total return of Kvichak River sockeye salmon versus number of spawners, 1956-1995 brood years.

Kvichak River Sockeye Salmon



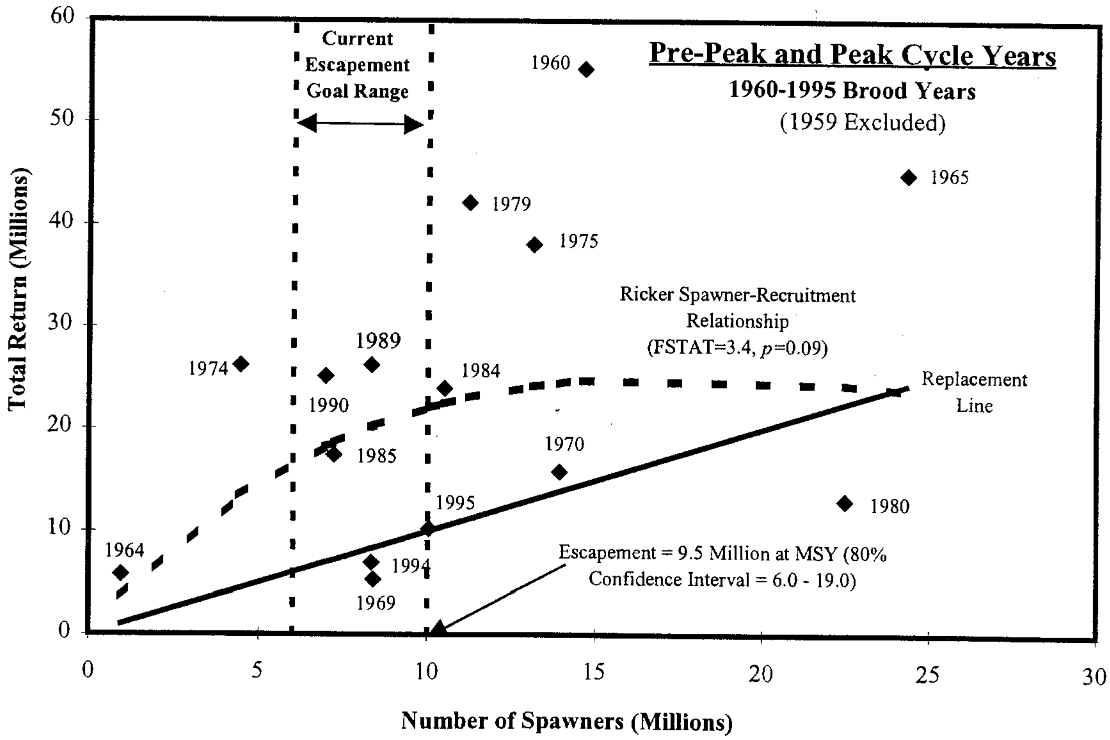


Figure 8. Ricker spawner-recrutiment relationship of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1960-1995 brood years).

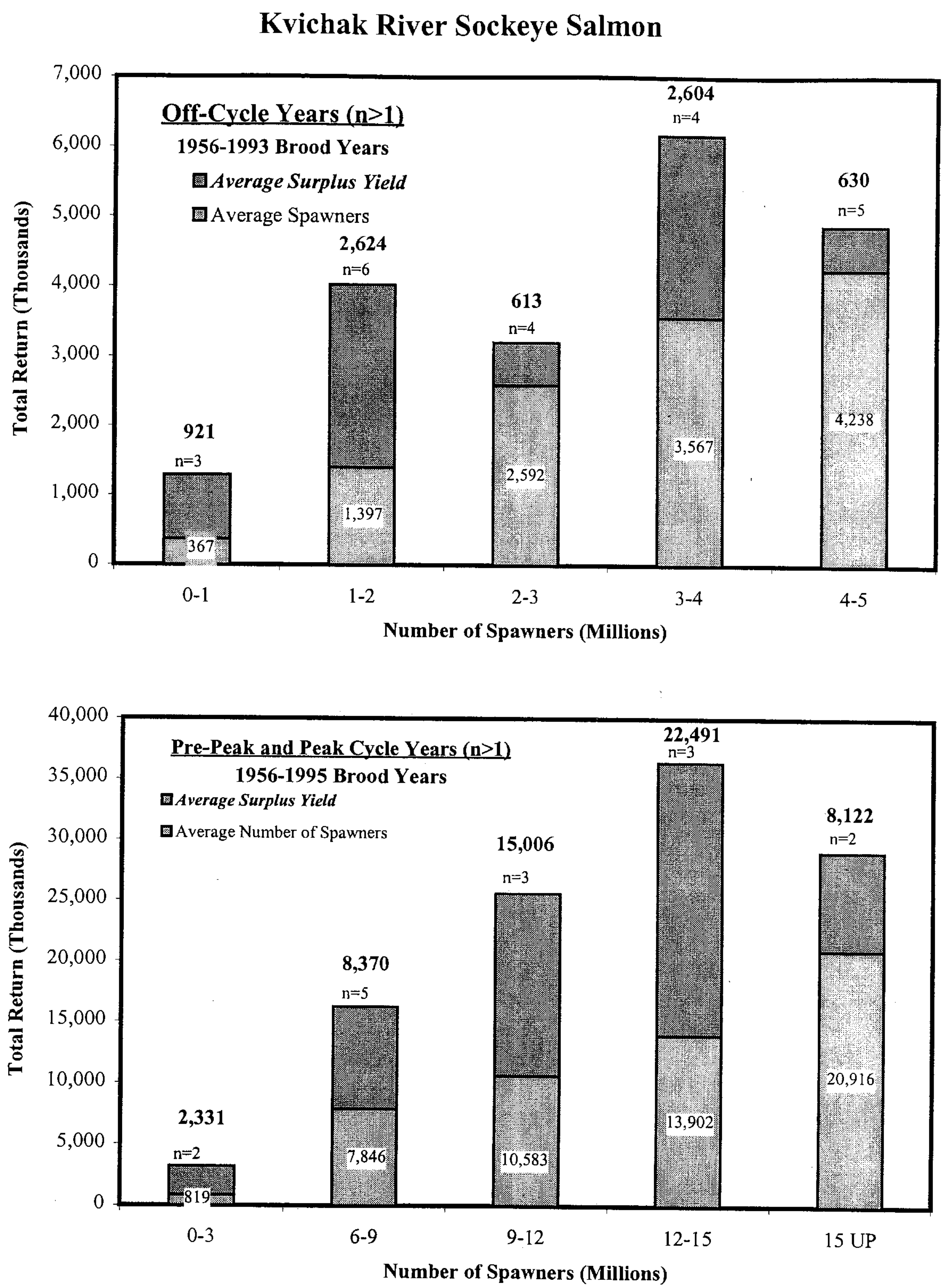


Figure 9. Average surplus yield categorized by number of spawners of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1960-1995 brood years).

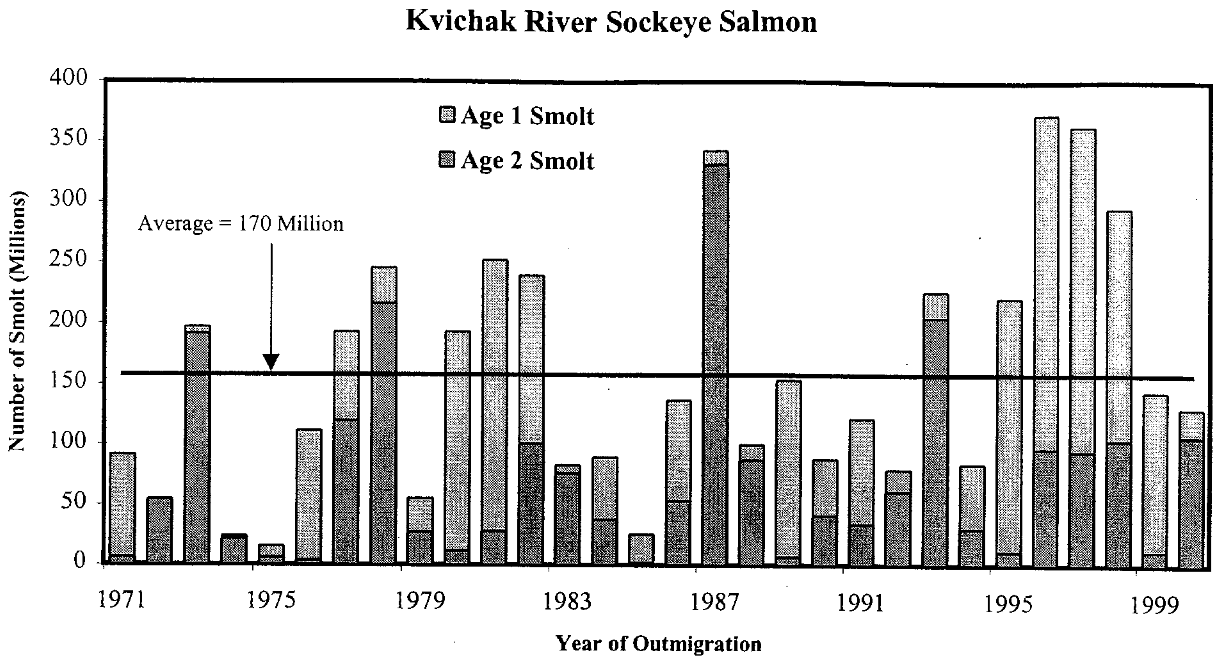


Figure 10. Number of sockeye salmon smolt migrating out of Kvichak River, 1971-2000.

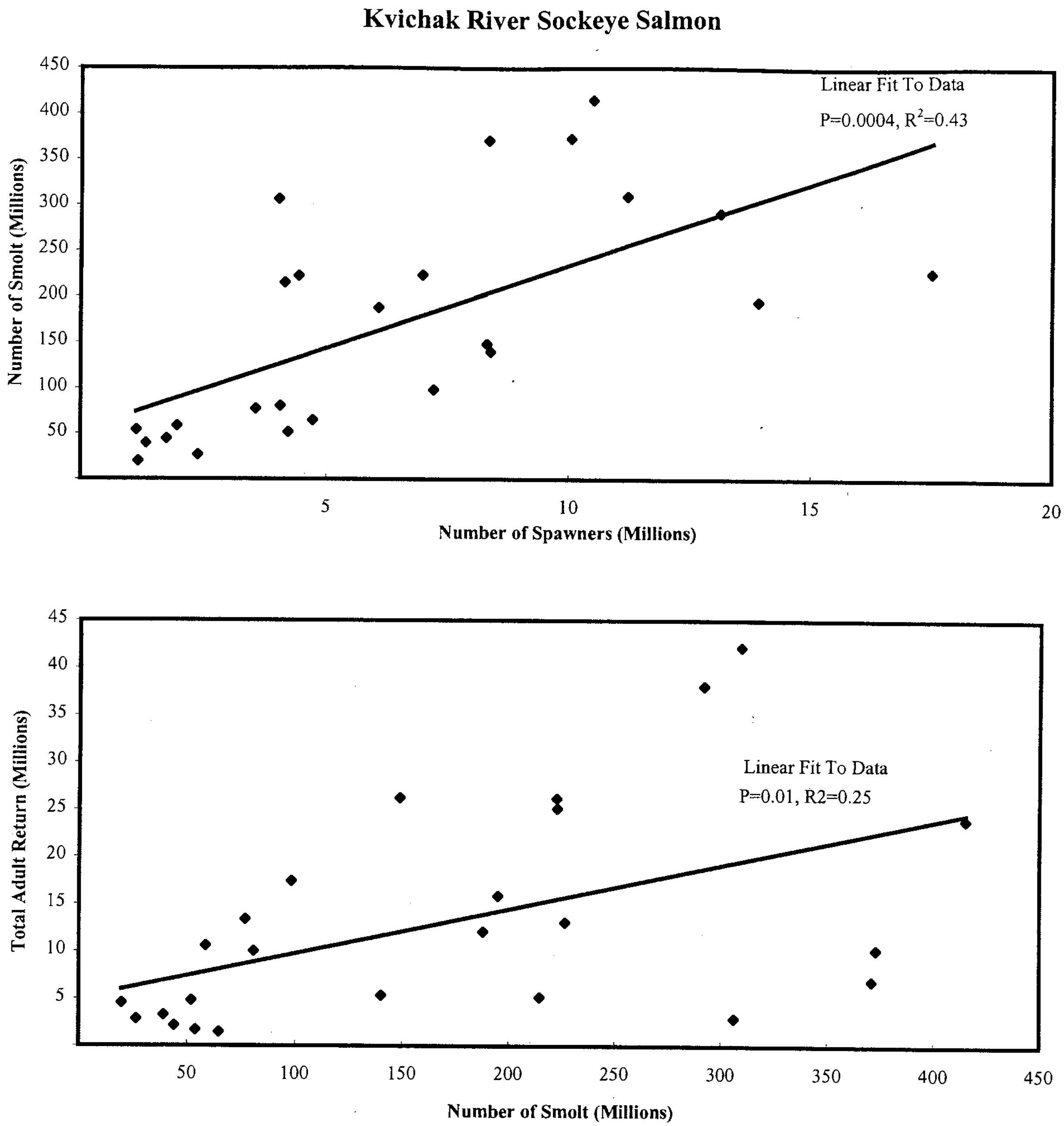


Figure 11. Number of spawners versus number of smolt, and number of smolt versus total adult return for Kvichak River sockeye salmon (1969-1995 brood years).

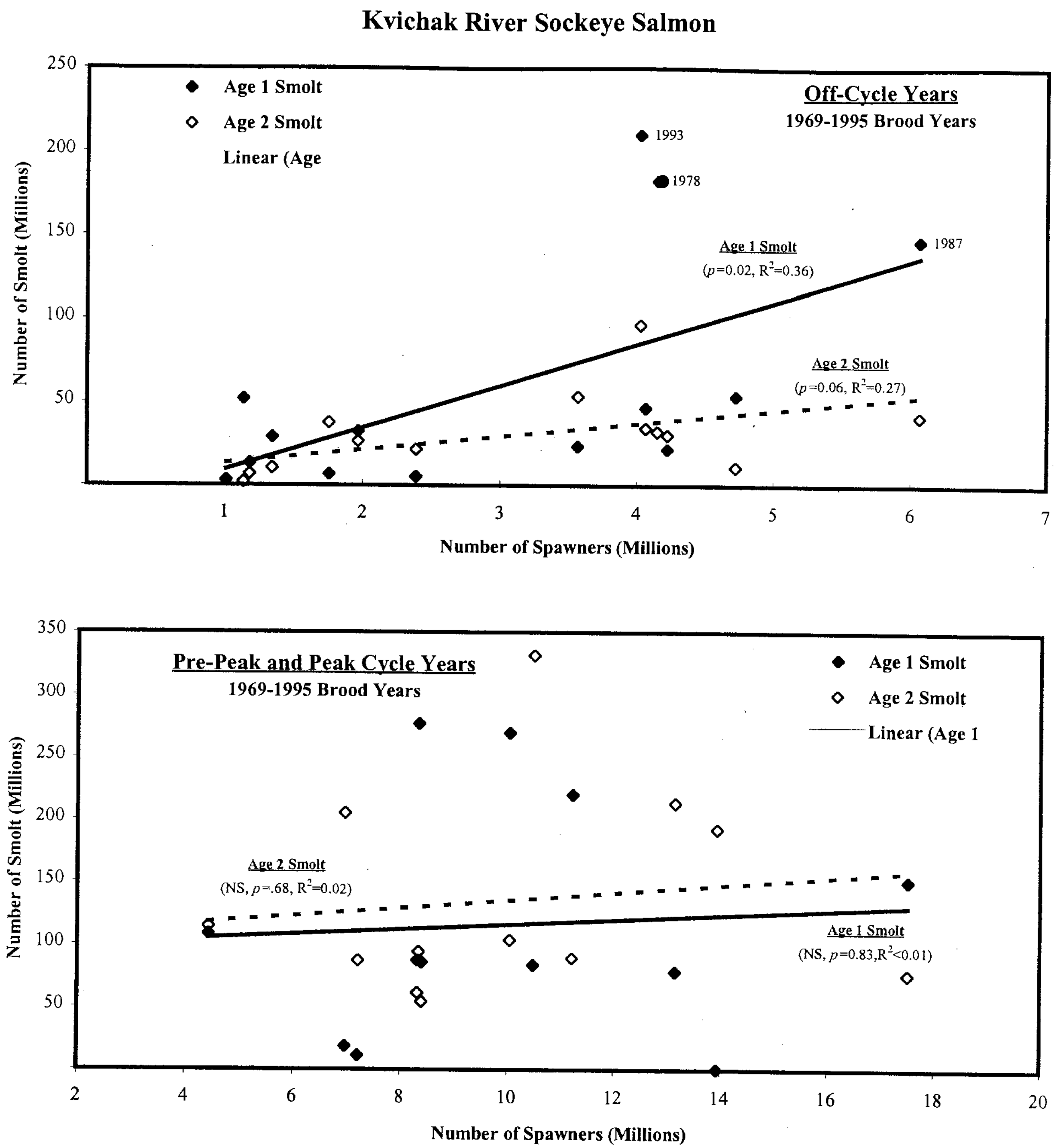


Figure 12. Number of spawners versus number of smolt of Kvichak River sockeye salmon for off-cycle, and pre-peak and peak cycle years (1969-1995 brood years).

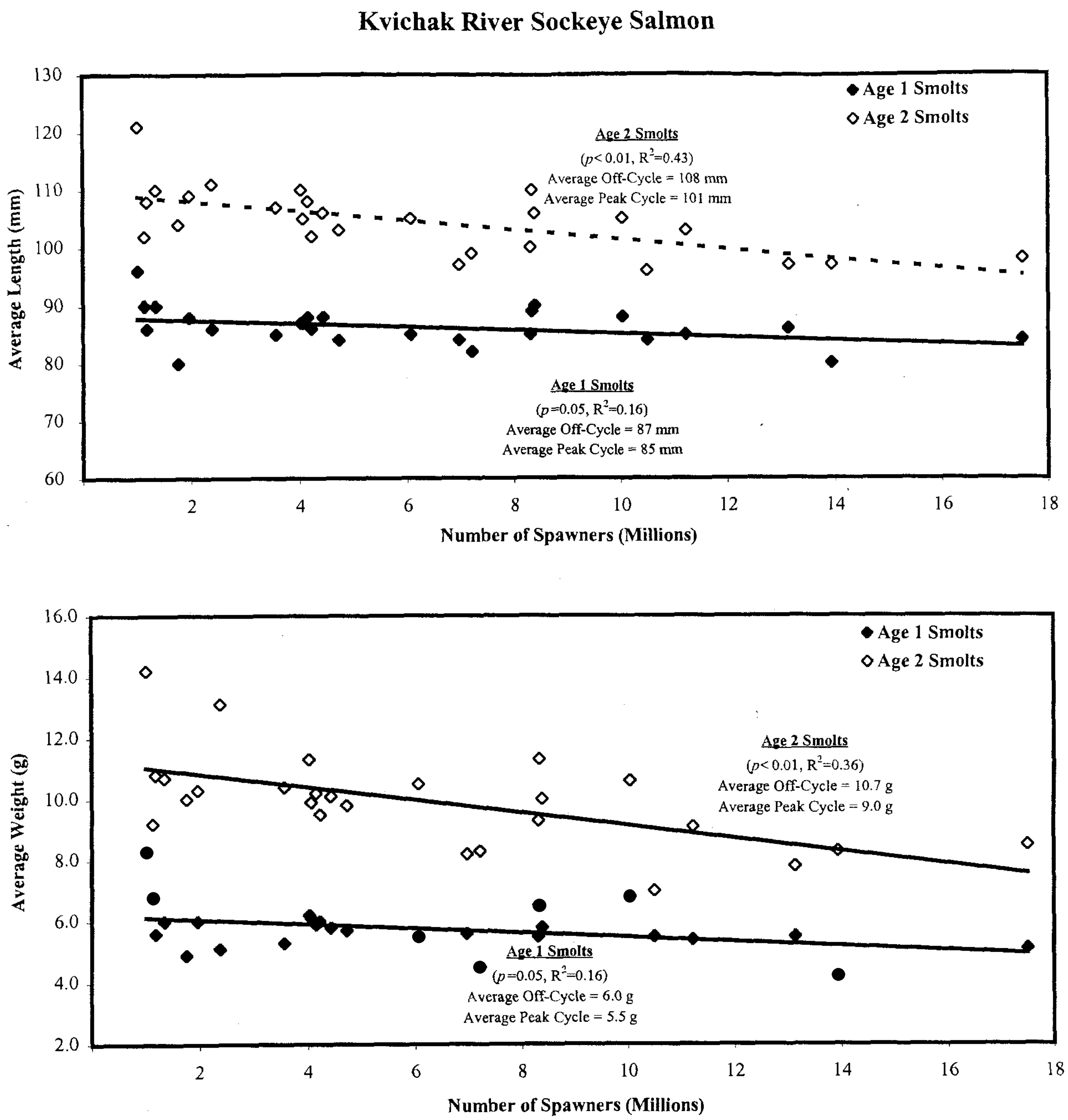


Figure 13. Average length and weight of age 1 and age 2 smolts versus number of spawners for Kvichak River sockeye salmon (1969-1995 brood years).

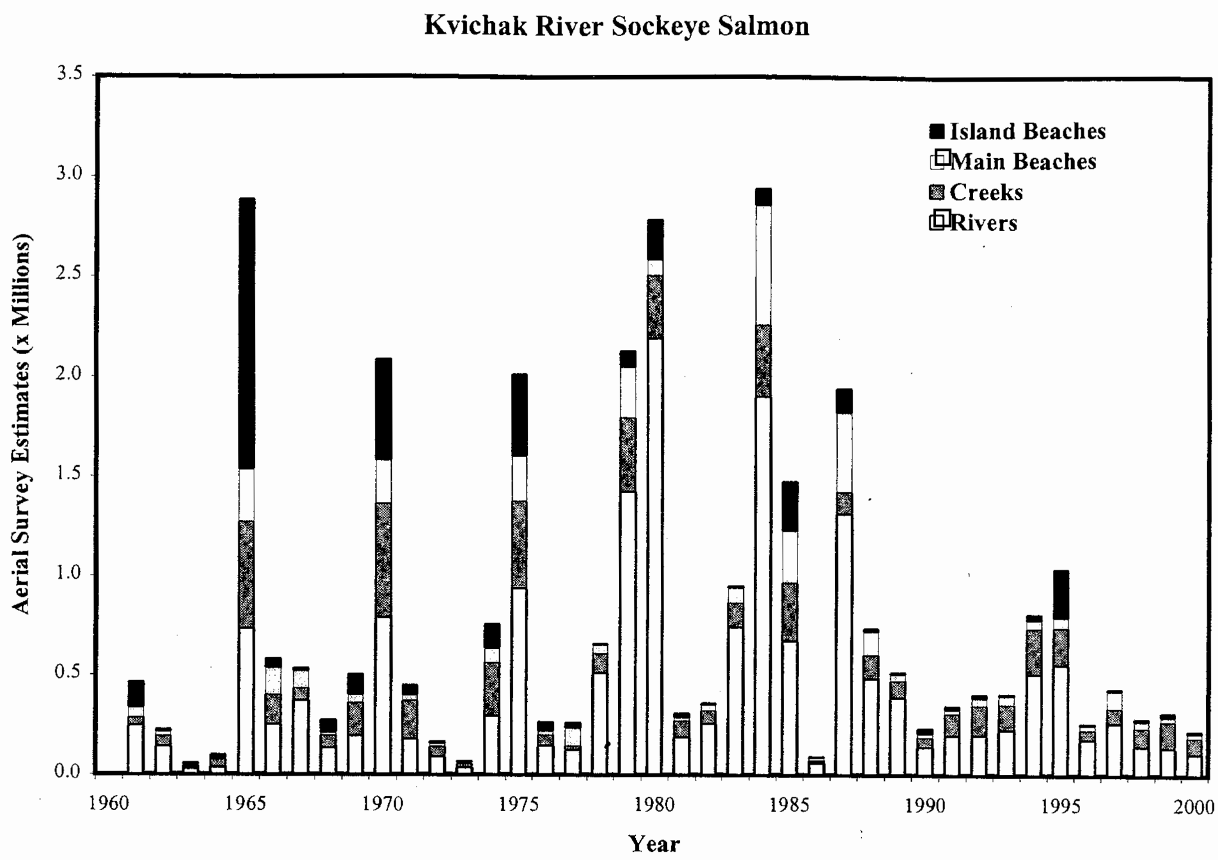


Figure 14. Spawner distribution of Kvichak River sockeye salmon at main beaches, island beaches, rivers and creeks, 1961-2000.

MANAGEMENT ACTION PLAN OPTIONS FOR ADDRESSING STOCK OF CONCERN AS OUTLINED IN THE SUSTAINABLE FISHERIES POLICY

KVICHAK RIVER SOCKEYE SALMON MANAGEMENT PLAN REVIEW/DEVELOPMENT

Current Stock Status

In response to the guidelines established in the Sustainable Salmon Fisheries Policy, the Board of Fisheries during the September 28-29, 2000 work session classified the Kvichak River sockeye salmon stock as a yield concern. This determination was based on the inability, despite the use of specific management measures, to maintain expected yields, or harvestable surpluses, above the stock's escapement for three of the past five years.

C&T use finding and the amount necessary

The Board of Fisheries has made a positive finding for Customary and Traditional Use for all salmon in the Bristol Bay area of 157,000 to 172,171 salmon. There are no Amount Necessary determinations that are specific for Kvichak River drainage.

Habitat Factors Adversely Affecting The Stock

There are no habitat factors adversely affecting the Kvichak stock within the entire drainage.

Do New Or Expanding Fisheries On This Stock Exist?

Presently, there are no new or expanding fisheries on this stock. There are three proposals that would create new or expanding fisheries on this stock. Proposal 28 allocates 2.5 million pounds of Kvichak sockeye salmon to a village on the Kvichak River for commercial gain, utilizing fish traps and/or fish wheels of which both gear types are not legal gear in Bristol Bay. Proposal 84 creates a Kvichak inriver fishery, which currently at this time does not exist. Proposal 85 opens the closed waters between Egegik and Naknek/Kvichak Districts to commercial fishing.

Existing Management Plans

Board reviews existing management plan for consistency with principles and criteria of Sustainable Salmon Fisheries Policy or adopts new management for the stock consistent with the principles and criteria of the Sustainable Salmon Fisheries Policy. The following are the current regulations:

5 AAC 06.200.FISHING DISTRICTS, SUBDISTRICTS, AND SECTIONS.

5 AAC 06.310. FISHING SEASONS.
5 AAC 06.320. FISHING PERIODS.
5AAC 06.355. BRISTOL BAY COMMERCIAL SET AND DRIFT GILLNET SOCKEYE SALMON FISHERIES MANAGEMENT AND ALLOCATION PLAN.
5 AAC 06.359. EGEGIK RIVER SOCKEYE SALMON SPECIAL HARVEST AREA MANAGEMENT PLAN.
5 AAC 06.360. NAKNEK RIVER SOCKEYE SALMON SPECIAL HARVEST AREA MANAGEMENT PLAN.
5 AAC 06.364. NAKNEK/KVCHIAK DISTRICT COMMERCIAL SET AND DRIFT GILLNET SOCKEYE SALMON FISHERIES MANAGEMENT AND ALLOCATION PLAN.
5 AAC 06.365. EGEGIK DISTRICT COMMERCIAL SET AND DRIFT GILLNET SOCKEYE SALMON FISHERIES MANAGEMENT AND ALLOCATION PLAN.
5 AAC 09.200 DESCRIPTION OF DISTRICTS AND SECTIONS.
5 AAC 09.310 FISHING SEASONS.

Identify Research Needed On Stock

See Page 38

ACTION PLAN DEVELOPMENT

Kvichak Sockeye Salmon Action Plan Goal

To rebuild the Kvichak sockeye salmon run back to historical levels by attaining the BEG.

Action Plan Alternatives

ACTION 1. Lower the exploitation rates on Kvichak stocks within the Naknek/Kvichak District.

Objective: Modify existing management plans to further reduce the exploitation rate of Kvichak stocks within the Naknek/Kvichak District when necessary.

Background: Current production within the Kvichak drainage is not resulting in sockeye salmon production at a level of yield produced in the past on an annual basis. Management plans currently in use when the Kvichak system is below average are tied to the Naknek/Kvichak and Egegik Districts. The two plans: 1) The Naknek River Sockeye Salmon Special Harvest Area Management Plan (NRSHA) allows the department to continue trying to achieve Kvichak river sockeye salmon spawning escapement while providing opportunities to harvest Naknek River salmon stocks that are in excess of spawning goals. 2) The Egegik River Sockeye Salmon Special Harvest Area Management Plan (ERSHA) allows the department to potentially minimize the interception of sockeye salmon migrating through the Egegik district while providing opportunities within the Egegik District to harvest Egegik River sockeye salmon that are in excess of the spawning goals.

During years when the total return to the Kvichak River can withstand an exploitation rate of approximately 40% or above, the current plans are adequate; however, there are drawbacks to inriver fisheries for Naknek and Egegik such as a concern for other species and quality of escapement. When returns cannot withstand an exploitation rate greater than approximately 40%, the current plans react too late to the situation. The current management plans dictate that when the Kvichak run falls two or more days behind the curve in reaching the escapement goal, drift gear comes out of the district and goes into the Naknek River. In addition, set gillnet gear remains out in the district but the amount of gear allowed to fish is reduced from 50 to 25 fathoms each. When it is demonstrated that the Kvichak will not meet the minimum biological escapement goal, the Naknek/Kvichak District closes, set gillnet gear follows drift gear into the NRSHA and Egegik District western boundary is moved to the Loran 110 line as specified in the ERSHA.

The Naknek River Special Harvest Area has been used six seasons since it's inception in 1986. The first time was in 1986, the total return to the Kvichak was 2.5 million sockeye, the escapement goal of 5-million was not achieved. The final escapement count of 1.2-

million was the end result. The drift fleet went into the Naknek River on July 9, 9-days behind the 5-million escapement goal curve, escapement at that point was 221,000 only four percent of the goal while the return on July 9 is historically 62% complete. Set gillnet gear went in-river on July 16.

The NRSHA was next used in 1996 and has been used every year since. The total return to the Kvichak drainage 1996 was 3.5 million sockeye, the escapement goal of 4-million was not achieved, 1.5 million sockeye was the final count. The NRSHA opened on July 4 for both gear groups, Kvichak escapement was 5.5 days behind the 4-million escapement goal curve, escapement was only 4% of the goal for that date and return was 28% complete. In 1997, total return to Kvichak was 1.7 million with an escapement goal of 4-million. The NRSHA was opened on July 9 to both gear groups, Kvichak escapement was 5.5 days behind the 4-million goal curve, escapement was 20% of the goal and the run was 62% complete.

During the 1997 winter BOF meeting the Kvichak escapement goal was changed for off-cycle years to a range of 2-10 million, the point goal being 50% of the total return within the range. In addition, the BOF established the current triggers when each gear type enters the NRSHA and the authority to fish the gear types separately. The total return to the Kvichak River in 1998 was 3.4-million making the escapement goal 2.0 million sockeye. The NRSHA was enacted on July 7 to drift gillnet gear only, Kvichak escapement was 2-days behind, escapement was 28% of the goal and the return was 48% complete. The goal of 2.0 million was met on July 13. In 1999, which was a pre-peak year the escapement goal was a range of 6 to 10-million with the mid-point being 50% of the run within that range. The total return to the Kvichak River was 12.6 million and the escapement goal of 6.0-million was met. The NRSHA was used for the drift gillnet fleet on July 11. The Kvichak River was 2.5-days behind, escapement was 62% of the goal and the return was 75% complete. The return to the Kvichak in 2000 was the peak year and the goal was set the same as the pre-peak year with a range of 6 to 10-million. The total return was 2.8 million, less than half the minimum escapement goal. The NRSHA went in effect on the earliest date ever July 3. The Kvichak was 2.5 days behind and only 7% of the goal past the tower had been met and run timing was 22% complete. The entire District was closed on July 6 and the set gillnet fleet was moved into the NRSHA at that time. The Kvichak Section was open only to set gillnet gear during July 1-6. The final escapement past the Kvichak tower was 1.8-million sockeye. The ERSHA was in effect in any year after 1986 that the NRSHA was open to both gear groups and the Naknek-Kvichak District had been closed until further notice.

Specific action recommended to implement the objective

Earlier triggers for both the NRSHA and the ERSHA could result in additional savings of Kvichak River sockeye salmon. One option of an earlier trigger would be to reduce the number of days behind the escapement goal curve on the Kvichak River to enact the NRSHA and the ERSHA.

Cost/Benefits Analysis

During years of low returns Kvichak stock would receive some benefits from earlier triggers for inriver fisheries. The amount of benefit is unknown and may not necessarily guarantee achieving the BEG. There are potential costs that go along with an inriver fishery.

1) Lower product quality of the harvest.

2) Larger pulses of fish entering into the escapement when commercial fishing is not occurring in the traditional section areas outside the rivers.

3) High numbers of boats confined to small areas leading to disorderly fisheries.

4) Less precision balancing allocation issues between gear groups in-river.

5) Short notice fisheries for most of the season to control escapement.

6) Less precision managing for escapement within the BEG range.

7) Potential impacts to the escapement of other species such as chinook and chum salmon.

Subsistence issues/considerations
There would be no loss of subsistence opportunity in this plan.

Performance measures
The Kvichak BEG met annually, no in-river fisheries and a level of harvest occurs on the Kvichak stock that produces average yields.

Research plan to address stock of concern
A research plan is not applicable to this proposed action.

ACTION 2. Redefine the Naknek Section boundaries.

Objectives
To minimize the interception of Kvichak bound sockeye within the Naknek Section of the Naknek/Kvichak District. Define new Section boundary lines for both the Naknek and Kvichak Sections.

Background: Only in 1986, the first year the NRSHA was in effect, did the department make any adjustments to the Naknek Section. What effect it had on minimizing the harvest of Kvichak stocks was unknown at that time.

It has been determined through Scale Pattern Analysis (SPA) studies conducted between 1983-1995 that Kvichak sockeye are harvested in the Naknek Section during commercial fishing periods (Menard, 1997). To determine the effects within the Naknek Section a stock composition study was conducted in 1992 (Crawford, 1994) to determine the occurrence of Kvichak stocks in the Naknek Section and to what extent did they occur in different areas. The conclusions from the study was that the Naknek/Kvichak District was a large intermingling area for both stocks, and it could not identify any specific lines that would minimize the harvest of fish bound for either river.

Specific action recommended to implement the objective:
The department has no recommendation as to any specific line between the Naknek and Kvichak Section. Based on the conclusions of the 1992 stock composition report within the Naknek/Kvichak District, it could not specify one location over another that would minimize the harvest Kvichak stocks.

Cost/Benefits:
By reducing the Naknek Section some savings of Kvichak stocks would most likely occur. As to how much, this is unknown. The cost to reducing the Naknek Section is high, it would displace a number of set net sites and potentially move them into the Kvichak Section. In doing so, adjustments to the allocation plan would be required. It would place a large number of drift permits in a smaller area thereby creating an even more intense line fishery.

Subsistence issues/considerations
There would be no loss of subsistence opportunity in this plan.

Performance measures
The Kvichak BEG met annually, no in-river fisheries and a level of harvest occurs on the Kvichak stock that produces average yields.

Research plan to address stock of concern
A research plan is not applicable to this proposed action.

ACTION 3. Redefine the Egegik Section boundaries.

Objectives
To minimize the interception of Kvichak bound sockeye within the Egegik District, by changing the outside boundary.

Background: Currently, there is a regulation that reduces the outside boundary of the Egegik District when the Kvichak is behind in escapement and the Naknek-Kvichak District has been closed. In addition, as stated in the department comments for Proposal 30, ebb fishing has been reduced in Egegik District to reduce the interception of other stocks.

Specific action recommended to implement the objective

Based on the previously mentioned SPA studies the department cannot recommend specific locations for an outside boundary.

Cost/Benefits

A reduction in the Egegik outside boundary may result in additional savings of Kvichak stocks, however the department could not measure these potential savings.

The Kvichak sockeye run failed to meet its BEG in three of the last five years (1996, 1997 and 2000). To come up with an estimate of Kvichak sockeye salmon intercepted in the Egegik District for these three years, results from scale pattern analysis (SPA) studies conducted from 1983 to 1995 were used. For the Egegik District, the data are grouped from 1991 to 1995. This was done because the district's western boundary was changed in 1991 from Loran C line 9990-Z-45140 to Loran C line 9990-Z-45135. There also seems to be a positive correlation of the amount of Kvichak sockeye salmon intercepted with the size of the Kvichak return. The larger the Kvichak run the larger the interception rate and the smaller the Kvichak run the smaller the interception rate.

For the period 1991 to 1995 the median interception rate of Kvichak stocks in the Egegik catch was 2.8%, range 1.4% to 12.0%. Simply applying the 2.8% median would give the following estimates of Kvichak fish caught in the Egegik District during the years Kvichak escapement goals were not achieved.

Year	Estimated Interception (in thousands)	Range (in thousands)
1996	303	0-833
1997	210	0-577
2000	199	0-547

The department believes these estimates are likely high for several reasons: 1) the apparent positive correlation of smaller Kvichak runs producing smaller interception rates. None of the Kvichak runs from 1991 to 1995 were less than 8 million and two of the years were record runs of over 21 million. The 1996, 1997 and 2000 runs were all under 4 million. 2) The Egegik District was fished at the 110 line from July 8 in 1996, from July 6 in 1997, and from July 7 in 2000, until the end of the sockeye salmon season. 3) Along with the 110 configuration, there is the assumption that reducing the amount of fishing time on ebb tides would also reduce the interception of fish coming into the Egegik District from the north. Ebb fishing in the Egegik District was reduced to an average of 5.7 hours per tide fished in 1996, 5.2 hours per tide fished in 1997, and 3.2

hours per tide fished in 2000. This compares to 6.3 hours in 1993, 5.9 hours in 1994, and 6.5 hours in 1995.

Additional potential costs associated with a reduction in the size of the Egegik District:

1) Lower product quality of the harvest.

2) Larger pulses of fish entering into the escapement when commercial fishing is not occurring in the traditional section areas outside the rivers.

3) High numbers of boats confined to small areas leading to disorderly fisheries.

4) Less precision balancing allocation issues between gear groups in-river.

5) Short notice fisheries for most of the season to control escapement.

6) Less precision managing for escapement within the BEG range.

7) Potential impacts to the escapement of other species such as chinook and chum salmon.

Subsistence issues/considerations
There would be no loss of subsistence opportunity in this plan.

Performance measures
The Kvichak BEG met annually, no in-river fisheries and a level of harvest occurs on the Kvichak stock that produces average yields.

Research plan to address stock of concern
A research plan is not applicable to this proposed action.

ACTION 4. Redefine the Ugashik Section outside boundaries and create an in-river fishery.

Objectives
To minimize the interception of Kvichak bound sockeye within the Ugashik District, by changing the outside boundary and by creating an in-river fishery.

Specific action recommended to implement the objective

Based on the previously mentioned SPA studies and no more current information the department can not recommend specific locations for an outside boundary.

Cost/Benefits

A reduction in the Ugashik outside boundary may result in additional savings of Kvichak stocks, however the department could not measure these potential savings

The Kvichak sockeye run failed to meet its BEG in three of the last five years (1996, 1997 and 2000). To come up with an estimate of Kvichak sockeye salmon intercepted in Ugashik District for these three years, results from scale pattern analysis (SPA) studies conducted from 1983 to 1995 were used.

For the Ugashik District the median rate of Kvichak interception is 4.8% of the Ugashik catch, range 0.2% to 14.4%. Figure 1 shows a curve fitted to these data to predict the intercept rate of Kvichak fish applied to the Ugashik harvest. The following are estimates of Kvichak sockeye salmon caught in the Ugashik District for the three years the Kvichak escapement goal was not achieved:

Year	Estimated Interception (in thousands)	Range (in thousands)
1996	95	0-285
1997	22	0-66
2000	30	0-90

Taking into account that the Ugashik District drift fleet fished 178 hours in 1996 from June 24 to July 17, and 55 hours in 1997 between June 24 and July 27, and 53 hours from June 24 to July 25 in 2000, it is likely that the estimates of Kvichak fish caught in the Ugashik District for these years are high. The average amount of fishing time for June 24 to July 17 for 1983 to 1995 is approximately 190 hours.

Additional potential costs associated with a reduction in the size of the Ugashik District or the development of an inriver fishery:

1) Lower product quality of the harvest.

2) Larger pulses of fish entering into the escapement when commercial fishing is not occurring in the traditional section areas outside the rivers.

3) High numbers of boats confined to small areas leading to disorderly fisheries.

4) Less precision balancing allocation issues between gear groups in-river.

5) Short notice fisheries for most of the season to control escapement.

6) Less precision managing for escapement within the BEG range.

7) Potential impacts to the escapement of other species such as chinook and chum salmon.

Subsistence issues/considerations
There would be no loss of subsistence opportunity in this plan.

Performance measures
The Kvichak BEG met annually, no in-river fisheries and a level of harvest occurs on the Kvichak stock that produces average yields.

Research plan to address stock of concern
A research plan is not applicable to this proposed action.

Research Plan

Past Research and Publications

Anderson, Cindy J. 2000. Counting Tower Projects in the Bristol Bay Area, 1955-1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A00-08, Anchorage.

Anderson, John W. 1968. Addendum to spawning ground catalog of the Kvichak River system, Bristol Bay, Alaska. Fisheries Research Institute, College of Fisheries, University of Washington, Seattle.

Barker, Morris. 1979. Summary of Salmon Travel Time From Tagging Studies, 1950-1974. Washington Department of Fisheries Technical Reports, Technical Report No. 48.

Baxter, Richard A. 1968. Primary Production in Iliamna Lake, Alaska. 1962-1967. M.S. Thesis, Univ. Washington, Seattle.

Burgner, R. L. Study of Population Density and Competition Between Populations of Young Red Salmon and Sticklebacks. Fisheries Research Institute, University of Washington, Seattle, Miscellaneous Reports, Bristol Bay.

Catalog of Waters Important for Spawning, Rearing or Migration of Anadromous Fishes. 1993. Alaska Department of Fish and Game, Habitat Division.

Crawford, Drew L. 2000. Bristol Bay Sockeye Salmon Smolt Studies for 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A00-18, Anchorage.

Cross, B. A., D. C. Gray, and D. L. Crawford. 1997. Report to the Alaska Board of Fisheries on spawning escapement goal evaluations for Bristol Bay salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A97-30, Anchorage.

Demory, Robert L., Russell F. Orrell, and Donald R. Heinle. 1964. Spawning ground catalog of the Kvichak River system, Bristol Bay, Alaska / compiled by Washington: U.S. Dept. of the Interior, Fish and Wildlife Service.

Donaldson, John R. 1966. The Phosphorus budget of Iliamna Lake, Alaska as related to the cyclic abundance of sockeye salmon.

Eggers, Douglas M. 1995. Harvest Rates by the South Unimak and Shumagin Islands June Fishery on Northwest Alaska Summer Chum Salmon, 1979-1994, and Bristol Bay Sockeye Salmon, 1970-1994. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 5J95-05, Juneau.

Eggers, Douglas M., and D. E. Rogers. 1987. The cycle of runs of sockeye salmon Oncorhynchus nerka to the Kvichak River, Bristol Bay, Alaska: cyclic dominance or depensatory fishing? Pages 343-366 in H.D. Smith, L. Margolis, and C.C. Wood, editors. Sockeye salmon Oncorhynchus nerka population biology and future management. Canadian Special Publications of Fisheries and Aquatic Sciences 96, Ottawa, Canada.

Eggers, Douglas M., Katherine Rowell, and Bruce Barrett. 1988. The Stock Composition of Catches of Sockeye and Chum Salmon in the 1987 South Peninsula June Fishery Based on Tagging. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J88-03.

Glick, B., K.A, Weiland, J.B. Browning, and S. Morstad. 2000. Salmon spawning ground surveys in the Bristol Bay Area, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A00-04, Anchorage.

Gray, Daniel C., and Michael R. Link. 1999. Abundance, Age, Sex, and Size statistics for Pacific Salmon in Bristol Bay, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A99-37, Anchorage.

Gray, Daniel C. 2000. Bristol Bay Sockeye Salmon Spawning Escapement Test Fishing, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A00-28, Anchorage.

Hoag, Stephen H. 1972. The Relationship between the summer food of Juvenile sockeye salmon, *Oncorhynchus nerka*, and the Standing Stock of Zooplankton in Iliamna Lake, Alaska. NOAA Fish. Bull. 70(2): 355-362.

Horton, Howard F., and James C. Olsen. 1962. Spawning Density Study of Red Salmon in Copper River, Iliamna Lake, Alaska. Fisheries Research Institute, University of Washington, Seattle.

Kerns, Orra E., Jr., and John R. Donaldson. 1968. Behavior and Distribution of spawning sockeye salmon on island beaches in Iliamna Lake, Alaska, 1965. J. Fish. Res. Bd. Canada 25(3): 485-494.

Lowry, Lloyd, Robert R. Nelson, and Kathrine J. Frost. 1985. Radiotagging Studies of Belukha Whales *Dephinapterus Leucas* in Bristol Bay, Alaska. Alaska Department of Fish and Game.

Mathisen, Ole A. 1969. Growth of sockeye salmon in relation to abundance in the Kvichak District, Bristol Bay, Alaska. FiskDir. Skr. Ser. HavUnders. 15:172-185.

Mathisen, Ole A., Parker P. L., J. J. Goering, T. C. Kline, P. H. Poe, and R. S. Scalan. 1988. Recycling of Marine Elements Transported into Freshwater Systems by Anadromous Salmon. Verh. Internat. Verein. Limnol. 23:2249-2258.

Menard, Jim, and James D. Miller. 1997. Report to the Alaska Board of Fisheries on the Stock Composition of Sockeye Salmon Catches Within East Side Bristol Bay Fishing Districts, 1983-1995. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A97-31, Anchorage.

Pennoyer, Steven and Michael L. Nelson. 1967. Summary of Bristol Bay Tagging Studies, 1950-1966. Alaska Department of Fish and Game, Division of Commercial Fisheries, Bristol Bay Data Report No. 13.

Poe, Patrick H. 1970. Sockeye Salmon Spawning Ground Studies in the Kvichak River System, Alaska, 1969. Fisheries Research Institute, University of Washington, Seattle.

Straty, Richard R. 1975. Migratory Routes of Adult Sockeye Salmon, *Oncorhynchus nerka,* in the Eastern Bering Sea and Bristol Bay. NOAA Technical Report NMFS SSRF-690.

Swanton, Charles O., and Robert L. Murphy. 1992. Origins of Sockeye Salmon Caught Within the Harbor Point to Strogonof Point Reach of the Alaska Peninsula Management Area, 8-21 July, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report No. 92-04.

Unpublished Reports and Memorandums

Rogers, D. E., and P. H. Poe. 1984. Escapement goals for the Kvichak River system. Unpublished Report FRI-UW-8407, Fisheries Research Institute, University of Washington, Seattle.

Geiger, Hal, Charles Swanton, and Bev Cross. Nov. 1995. <u>Subject:</u> Review of North Alaska Peninsula Scale Pattern Analysis with emphasis on Swanton and Murphy, 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Memorandum addressed to Peter J. Probasco and John Hilsinger, 1995.

Probasco, Peter J. and John Hilsinger. Jan. 1996. <u>Subject:</u> Review of Memorandum written by Geiger, Hal, Charles Swanton and Bev Cross on North Alaska Peninsula Scale Pattern Analysis with emphasis on Swanton and Murphy, Alaska Department of Fish and Game, Division of Commercial Fisheries, Memorandum addressed to Bob Clasby, 1996.

Current Bristol Bay Research Projects

<u>Project Name:</u> Kvichak Inriver Test Fishing. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Description: This is an existing inriver test fishing project funded under ADF&G Test Fish Fund Program Receipts. ADF&G personnel catch sockeye salmon in the Kvichak River with a 25 fathom drift gillnet fished daily at two sites located on opposite river banks prior to every high slack tide. This information is used to estimate the number of sockeye salmon which have escaped the commercial fishery and entered the Kvichak River to spawn. Since about 80% of the run occurs within a two week period, and there is one to three day delay in counting salmon at upriver towers, early estimates of escapement from the test fishery are used to control the commercial harvest and achieve the biological escapement goal. Although salmon are sold by ADF&G personnel in the name of the State under a special permit, it is not possible to generate sufficient revenues to pay for the project without compromising the project's scientific purposes.

Project Name: Bristol Bay Salmon Scale Processing and Aging. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Location: Naknek-Kvichak, Egegik, Ugashik, Nushagak, and Togiak Districts

Description: Adult sockeye, chum, chinook and coho salmon scales obtained from commercial catches, test fishing catches, escapement samples, and smolt samples are processed, read, and cataloged. Ages, as well as additional information on sex, length, and weight, are entered into a computer database for use in constructing brood year production tables and tracking age and growth trends.

Project Name: East Side Catch Sampling. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Location: Naknek-Kvichak, Egegik, and Ugashik Districts

Description: Sockeye, chinook, chum and coho salmon are sampled from dockside and floating processors located in Naknek-Kvichak, Egegik, and Ugashik Districts. Information collected includes species, length, weight, sex, and a scale for age determination. Data are used to estimate age, sex, and size composition of commercial catches. This information is used to construct brood year tables needed to track production, examine spawning goals, and forecast adult returns.

Current Bristol Bay Research Projects Funded and Operating Under Western Alaska Disaster Mitigation Funds

Project: Juvenile Sockeye Salmon Assessment and Limnological Investigations of Lake Iliamna. Project Leaders: Edmundson, Jim A., and Bruce Finney. Alaska Department of Fish and Game, Division of Commercial Fisheries. Proposed Operating Years 1999-2002.

Description: As the first phase of this 3 year project, a thorough review of existing literature would be completed to compile and summarize existing data. This would help determine the most useful information to collect in the future, and prevent conducting further surveys that would not contribute significantly to existing information. Phase I would also include baseline limnological studies (e.g., plankton distribution) and refinement of field methods.

Project: Genetic Stock Identification. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Location: Naknek-Kvichak, Egegik, Ugashik, Nushagak, and Togiak Districts

Description: Samples from sockeye salmon collected at major spawning sites within each District will be processed and analyzed at the Anchorage Genetics Laboratory. Various techniques may be examined and used. These might include mitochondrial DNA analysis of scales and various body tissues, and protein electrophoresis of various body tissues. It will take several years to sample and analyze data from the many spawning populations to adequately describe stock groupings and develop models that will provide stock mixture estimates of sufficient accuracy and precision.

Project: Evaluation of Bristol Bay Sockeye Salmon Smolt Enumeration Techniques and Development of New Sonar System. Alaska Department of Fish and Game, Division of Commercial Fisheries. Proposed Operating Years 1999-2002.

Description: Hydroacoustic equipment has been used to estimate smolt numbers for selected river systems in Bristol Bay since the early 1970's. Although some modifications and improvements have been made, a thorough evaluation of counting procedures and sonar equipment has never been conducted. The sonar equipment currently used was designed and built in the early 1980's. Technological advances made since then may improve our ability to estimate smolt numbers.

Professional sonar experts will be contracted to evaluate all phases of existing smolt projects including: sonar equipment, counting procedures, sampling methods, and site locations. The final product of these investigations will be the development of a new sonar system for counting smolt in Bristol Bay along with detailed operation plans for site selection, counting procedures, and sampling methods.

Project: Evaluation of Inriver Test Fishing Projects. Alaska Department of Fish and Game, Division of Commercial Fisheries. Proposed Operating Years 1999-2002.

Description: Spawning escapement estimates based on test fishing data play an important role in management decisions. Test fishing information allows escapement estimates to be made several days prior to when the salmon can be visually counted from observation towers located over clear water near lake outlets. Test fishing projects have been operated on Kvichak River since 1960, on Ugashik River since 1961, on Egegik River since 1963, and on Igushik River since 1976. Although small improvements continue to be made to these projects, a thorough evaluation of test fishing procedures and equipment has not been made since the early 1980's. Fish behavior at test fishing sites may change over time due to alterations of rivers by siltation, tidal influence, storms, and other factors. This in turn may require changes in the way existing sites are fished or relocation to new sites to improve the accuracy of escapement estimates based on test fishing data.

Project: Evaluation and Improvement of the Nushagak River Sonar Project. Alaska Department of Fish and Game, Division of Commercial Fisheries. Proposed Operating Years 1999-2002.

Description: Current acoustic equipment used to count salmon escaping into the Nushagak River was constructed in the early 1980's and only esonifies 18% of the river width. Results from extensive test netting have shown that significant numbers of chinook and coho salmon migrate outside the sonar range and are not counted with the current system. In addition, the current system is single beam and cannot fix the location or orientation of the targets. Technological advances in acoustic equipment and configuration will improve our ability to count the numbers of salmon, especially chinook salmon, escaping into the Nushagak River.

Professional sonar experts will be contracted to evaluate all phases of counting adult salmon migrating up the Nushagak River. The investigation will include site selection, equipment configuration, software development, and some definitions of fish behavior (lateral and vertical distribution, and upstream/downstream movement). The final product of these investigations will be the development and implementation of a new sonar system for counting adult salmon escaping into the Nushagak River with detailed operation plans for site selection, counting procedures, and sampling methods.

Project: Nushagak District Modeling and Escapement Goal Evaluation. Alaska Department of Fish and Game, Division of Commercial Fisheries. Proposed Operating Years 1999-2002.

Description: This program funds the personnel and equipment necessary to collect additional sockeye salmon escapement information from the Nuyakuk River and develop a fishery model of the Nushagak District. The Nushagak District Model will be used to evaluate escapement goals into the Wood, Nushagak, and Igushik Rivers taking into account joint spawner-recruit relationships, joint yields, past fisheries management performance, and examine alternative harvest scenarios. The three years of escapement data for the Nuyakuk River will provide information on the distribution of spawners in the Nushagak River system. This data is complementary to information in the historical database and has the potential of shedding light on the variation in production in the Nushagak system.

Proposed ADF&G Bristol Bay Research Projects

Project I-C: Naknek River Sockeye Salmon Smolt Enumeration. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Description: Using existing Bendix sonar equipment, sockeye salmon smolt will be counted as they migrate seaward from the Naknek River system. Age and size information will be collected from sockeye salmon smolt captured near the counting site with fyke nets or traps. Smolt numbers and biological information provide data needed to evaluate freshwater production, set biological escapement goals, and forecast adult returns.

Project V-A: Distribution and Relative Abundance of Adult Sockeye Salmon in Unassessed Systems. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Location: Naknek-Kvichak, Egegik, Ugashik, Nushagak, and Togiak Districts

Description: Sockeye salmon spawners will be counted from fixed or rotary wing aircraft in systems (or portions of systems) not currently assessed or surveyed. This project will attempt to obtain peak counts in systems not included in the current assessment program. Such data cannot be used to estimate total escapement into these systems, since survey frequency would have to be greatly increased and information on stream life and observer efficiency would have to be collected. Peak counts, as well as presence and absence information, can be used to identify anadromous streams and monitor the status of populations not currently surveyed. Although such information is very important, its use in setting biological escapement goals and predicting future returns is very limited.

Project V-B: Development of Video Technology for Escapement Enumeration. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Location: Naknek-Kvichak, Egegik, Ugashik, Nushagak, and Togiak Districts

Description: The use of video cameras to count Pacific salmon will be evaluated. This project could decrease the cost of escapement monitoring and increase the number of systems monitored. Use of video equipment would also provide a visual record of salmon passage that would be available for future review and analysis. Escapement projects provide data needed to evaluate management strategies and set biological escapement

Project V-F: Branch River Sockeye Salmon Escapement Enumeration. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Description: Sockeye salmon will be counted from towers on each bank of Branch River as they migrate upstream to tributary lakes and streams to spawn. Age, size and sex information will be collected from sockeye salmon captured near the counting site with beach seines. Escapement and biological information provide data needed to evaluate management strategies and set spawning escapement goals.

Project VI-A: Collaborative ecosystem study of sockeye salmon in the near-shore marine environment. Central Region Project Bluebook, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries.

Description: This is intended to be a sub-component of a larger project conducted in concert with a cooperating research agency or institution. Support of a research vessel from the cooperating agency is essential for this collaborative project. This funding component would provide field staff to collect marine plankton and stomach content samples; and support from the Central Region Limnology Lab to do data analysis of the samples.

USGS – BRD, Alaska Biological Science Center, Bristol Bay Research Projects

Project: Long-term Climate Effects on Bering Sea Salmon Growth and Production. Contact: Coggins, Lew. USGS – Alaska Biological Science Center. Proposed operating years 1999-2002.

Description: To contribute to the understanding of the effects of climate on salmon production by 1) investigating a general life history model of salmon production, meant to serve as a backbone for future modeling efforts and guide future research efforts, 2) surveying and inventorying existing salmon production and climate data germane to future salmon production modeling efforts, and 3) performing retrospective analysis of Bristol Bay sockeye salmon production by relating growth throughout the species' life history, as indicated in fish scales, and various relevant climate measures.

Project: Proposal Concept. Predation on Juvenile salmon upon entering nearshore marine areas of Bristol Bay. Contact: Nielsen, Jennifer. USGS – Alaska Biological Science Center.

Description: Learn more about an important component of early marine mortality: predation. The project will be phased such that the effects of various predators, such as belugas, seas birds, and fish, will be analyzed progressively over the next several years. A combination of standard and promising research techniques, such as stomach content analysis, molecular genetics, and lipid markers will be used to try to estimate the relative importance of various predators.

Project: Population Dynamics and Ecology of Lake Clark Sockeye Salmon. Contact: Woody, Carol Ann. USGS – Alaska Biological Science Center. Proposed operating years 1999-2002.

Description: Depletion or loss of sockeye salmon in this system has potentially serious ecological ramifications to the Lake Clark ecosystem, biodiversity, and on communities of vertebrate consumers. This study is designed as a collaborative interagency project for understanding the population structure of sockeye salmon and measuring exploitation rates by commercial, sport, and subsistence fisheries. Objectives include to: determine the population structure of Lake Clark sockeye salmon; asses in-Lake migratory routes, geographic and temporal distribution of spawning; investigate potential for local adaptation and differential selection regimes among populations; and identify populations of management concern and develop recommendations for their conservation.

LITERATURE CITED

Alaska Department of Fish and Game and the Alaska Board of Fisheries. 2000. Sustainable salmon fisheries policy for the State of Alaska. Alaska Department of Fish and Game, Juneau. 14 pp.

Crawford,D.L., J.D. Miller, B.A. Cross. 1994. Report to the Alaska Board of Fisheries on the stock composition of sockeye salmon catches made by test fisheries in the Naknek/Kvichak District, 1992, and Middle Bluff area, 1993-1994. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A94-45, Anchorage.

Cross, B. A. 1991. Report to the Alaska Board of Fisheries spawning escapement goal evaluation for Kvichak River sockeye salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A91-16, Anchorage.

Cross, B. A. 1994. Report to the Alaska Board of Fisheries on spawning escapement goal evaluation for Bristol Bay sockeye salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A94-46, Anchorage.

Cross, B. A., D. C. Gray, and D. L. Crawford. 1997. Report to the Alaska Board of Fisheries on spawning escapement goal evaluations for Bristol Bay salmon. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A97-30, Anchorage.

Eggers, D. M., and D. E. Rogers. 1987. The cycle of runs of sockeye salmon *Oncorhynchus nerka* to the Kvichak River, Bristol Bay, Alaska: cyclic dominance or depensatory fishing? Pages 343-366 in H.D. Smith, L. Margolis, and C.C. Wood, editors. Sockeye salmon *Oncorhynchus nerka* population biology and future management. Canadian Special Publications of Fisheries and Aquatic Sciences 96, Ottawa, Canada.

Fried, S. M. 1984. Bristol Bay Pacific salmon spawning escapement goal workshop. Alaska Department of Fish and Game, Division of Commercial Fisheries, Bristol Bay Data Report 84-12, Anchorage.

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaska and west coast Pacific salmon. Fisheries 24: 6-14.

Menard, J. and J. D. Miller. 1997. Report to the Alaska Board of Fisheries on the stock composition of sockeye salmon catches within the eastside fishing districts, 1983-1995. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A97-31, Anchorage.

Rogers, D. E., and P. H. Poe. 1984. Escapement goals for the Kvichak River system. Unpublished Report FRI-UW-8407, Fisheries Research Institute, University of Washington, Seattle.

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.